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PART I: BOTANY AND FORESTRY

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PART I: BOTANY AND FORESTRY

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EDITORS

GRACE E. POTTER AND FREDERICK K. SPARROW

PART I: BOTANY AND FORESTRY

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PART I: BOTANY AND FORESTRY

BOTANY

NEW RECORDS OF MYXOMYCETES FROM MICHIGAN*

CONST. J. ALEXOPOULOS AND E. S. BENEKE

A SEARCH of the pertinent literature, which consists of some eight papers dealing with the slime molds of Michigan, reveals that 115 species of Myxomycetes have been reported in print as occurring in this state. Several rather large collections of Myxomycetes have been made in Michigan, as is evidenced by the material in the herbaria of the University of Michigan and Michigan State College. V. M. Spaulding, Frances Landon, and L. N. Johnson deposited a number of specimens, collected chiefly near Ann Arbor, in the University of Michigan Herbarium at the end of the past century; the names of M. V. Cannon, C. H. Kauffman, E. B. Mains, J. V. A. Drummond, Bessie B. Kanouse, A. H. Povah, A. H. Smith, and T. E. Brooks are most frequently associated with the slime-mold collections of subsequent years. Among the larger, more recent collections are those of A. H. Povah and J. L. Lowe, from Isle Royale in the summer of 1930 (10), and of A. H. Smith and T. E. Brooks, from various parts of the state in the summer of 1946.

The Herbarium of Michigan State College contained until a short time ago only a very few specimens of Michigan slime molds; these had been collected chiefly by W. J. Beal, C. H. Hicks, B. O. Longyear, and C. F. Wheeler in the vicinity of East Lansing during the latter part of the last century and the first years of the present one. This herbarium has been recently enriched by the specimens collected by Miss Ruth Gilman (3) in the summers of 1936 and 1939 in Benzie County, Michigan, and generously donated to the herbarium by Dr. Joseph Gilman; by the specimens collected by us (Alexopoulos and Beneke) in the last three years; and, very lately, by the slime-mold developments on bark in moist-chamber cultures made by John E. Peterson, Jr. (7). Thus the number of species of

* Contribution No. 52–12 from the Department of Botany and Plant Pathology, Michigan State College.

Myxomycetes collected in Michigan up to 1952, as represented by specimens in the two major cryptogamic herbaria of the state, is actually about 145, rather than 115, the number recorded in the literature.

In 1949 we initiated a study of the Myxomycetes of Michigan, and since then we have collected in various parts of the state, particularly in regions which had not been extensively worked by others. Our Michigan collection now numbers 350 specimens, representing 86 species. Of these, the ones listed below are new to the state in the sense that no report of their occurrence in Michigan has been previously published and in that they are not represented by Michigan collections, except for our specimens, in the herbaria of the University of Michigan and Michigan State College.

The names of the organisms are those accepted by Martin (6); the numbers are our own.

List of Species

TRICHIALES

DIANEMACEAE

Margarita metallica (Berk.) Lister.—Nos. 5 and 6. Developed in moist chamber on bark of *Acer sp.* collected in East Lansing on January 6, 1949. This species is apparently not uncommon, but it is not collected frequently because of its minute size. Our two moist-chamber developments consist of but three or four sporangia each.

TRICHIACEAE

Perichaena chrysosperma (Currey) Lister.—Two collections: No 119, April 17, 1950, and No. 286, September 24, 1950, both on rotting wood, Baker woodlot, East Lansing. The plasmodiocarps are typically doughnut-shaped, but grade into long, straight rods.

Arcyria pomiformis (Leers) Rost.—Two collections: No. 407, August 20, 1950, on a fragment of a polypore, about four miles east of Michigamme, opposite Van Ripe Park; and No. 448, August 22, 1950, on old wood, near Cross Village. This is one of the smaller, inconspicuous species of Arcyria. It is prob-

ably much more common than would be supposed, as is indicated by the studies of Peterson (7), who found it frequently in his moist-chamber cultures.

TRICHIA ALPINA (R. E. Fries) Meylan.—Two collections: No. 382, August 19, 1950, on dead wood, Bergland School Forest; and No. 450, August 22, 1950, on bark, Michigan State Forest near Cross Village. Both collections are scanty, one consisting of five sporangia and the other of six. This interesting species has been reported from New England and from the West Coast states, but apparently has not been found previously in the Midwest. Comparison with authentic material from New England, kindly loaned to us by Dr. G. W. Martin, leaves no doubt of the identity of our specimens.

HEMITRICHIA LEIOCARPA (Cooke) Lister.—No. 412. Developed in moist-chamber culture on polypore fragments collected by G. R. Gleason on December 29, 1950, near East Lansing. The fruiting bodies developed from a watery, gray plasmodium. This species, easily recognized by its Arcyria-like aspect, has previously been known in the United States only from Maine, Pennsylvania, and Oregon, according to Martin (6).

CALONEMA AUREUM Morgan.—No. 81. September 11, 1949, on decaying wood, Warren Dunes, near Sawyer.

STEMONITALES

ECHINOSTELIACEAE

ECHINOSTELIUM MINUTUM De Bary.—No. 15. Developed in moist-chamber culture on elm bark collected on February 26, 1949, near East Lansing. This smallest of all Myxogastres is also probably the most abundant. Yet it has escaped the attention of collectors in Michigan because of its minute size. Sporangia develop by the hundreds on almost any piece of bark that is placed in a moist chamber for a week. Peterson (7) reports three distinct color types for this organism: pink, brown, and white. Our collection consists of the pink type, but we have also seen other color types. Whether the color differences are constant and worthy of varietal recognition is a question that needs investigation.

COMATRICHA CORNEA Lister & Cran.—No. 10. Developed in moist-chamber culture on bark of *Pinus sp.* collected on January 6, 1949, in East Lansing. In the United States the species is known only from Iowa and Kansas, and then only from moist-chamber cultures. The small collar at the base of the columella and the translucent stalk are the outstanding characteristics of this minute species.

COMATRICHA AEQUALIS Peck.—No. 341. August 18, 1951, on dead wood, Tahquamenon.

CLASTODERMA DEBARYANUM A. Blytt.—No. 25. Developed in moist-chamber culture on bark of *Acer sp.* collected by Miss Marie L. Ehrmann on April 10, 1949, in East Lansing. As in many moist-chamber cultures, this development consists of only a very few sporangia.

PHYSARALES

PHYSARACEAE

BADHAMIA OVISPORA Racib.—No. 14. Developed in moist-chamber culture on cow dung collected in February 1949 in East Lansing. Martin (6) gives Massachusetts, New York, Pennsylvania, and Colorado as the only states in this country from which the species has been reported.

CRATERIUM CONCINNUM Rex.—No. 341. August 19, 1951, on dead wood, Cut River bridge, on U. S. Highway No. 2. This is a scanty collection, of but a few sporangia.

PHYSARUM SUPERBUM Hagelst.—No. 394. August 19, 1950, on moss growing on decaying wood, near White Pine.

DIDYMIACEAE

DIDYMIUM MEGALOSPORUM Berk. & Curt.—No. 459. August 22, 1950, on dead leaves, woods near Harbor Springs.

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We express our grateful thanks to the Michigan Academy of Science, Arts, and Letters for a grant which partly supported this work; to Dr. E. B. Mains and Dr. Bessie B. Kanouse, of the University of Michigan Herbarium, for the use of the myxomycete

collection of the University; and to Dr. G. W. Martin, of the State University of Iowa, for the loan of authentic specimens for comparison.

MICHIGAN STATE COLLEGE
EAST LANSING, MICHIGAN

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SILICIFIED PLANT REMAINS FROM THE MESOZOIC AND TERTIARY OF WESTERN NORTH AMERICA

II. SOME FOSSIL WOODS FROM NORTHERN ALASKA*

CHESTER A. ARNOLD

THE woods described in this account were collected along the Colville River in northern Alaska during the summer of 1951, while I was exploring for fossil plants in Naval Petroleum Reserve No. 4 in connection with a project sponsored by the Office of Naval Research and the Arctic Research Laboratory at Point Barrow.

The material identified as *Xenoxylon latiporosum* (Cramer) Gothan was found at the "Big Bend" of the Colville River, about three air-line miles south of the mouth of the Awuna River. It came from the Chandler formation of the Nanushuk group (Gryc *et al.*, 6), which, on the basis of plants as well as of invertebrate fossils, belongs to the Lower Cretaceous. The specimen described as *Cedrus alaskensis*, sp. nov., was found about thirty-seven miles east of this spot, where the Oolamnagavik River joins the Colville. Although the rocks in this general region belong to the Nanushuk group, the strata at the place where the wood was found are much folded and faulted, so the exact position in the stratigraphic column cannot be given. However, the presence there of a three-foot seam of coal and of a few associated plant fragments indicates the Nanushuk group. Both specimens are therefore regarded as Lower Cretaceous.

Both woods are silicified. *Cedrus alaskensis* is a member of the Pinaceae, and *Xenoxylon latiporosum* belongs to that complex of Mesozoic gymnosperms commonly referred to as the "transition conifers." This term is derived from the fact that the members show characters in common with more than one family or genus of Recent Coniferales. *X. latiporosum* has been regarded by various

* Contribution No. 1952–4 based on work done under the auspices of the Arctic Research Laboratory of the Office of Naval Research.

authors (Holden, 8) as being araucarian, but it has some features of modern members of the Pinaceae and is at the same time quite distinctive in itself in a number of respects. Some species of *Xenoxylon* are said to be indistinguishable from *Sciadopitys* and *Podocarpus*.

There are numerous instances on record of fossil woods in the Mesozoic and Tertiary of the Arctic regions, but very few have hitherto been found in Alaska, and none, so far as is known, on the Arctic Slope.

Xenoxylon latiporosum (Cramer) Gothan

(Pl. I, Fig. 2; Pl. II)

The specimen is a small piece of what was evidently a trunk of considerable size. Although silicification had been thorough, much of the original organic matter remains in partly altered form. The shape and distribution of the pits on the tracheid walls are well preserved, but some of the chemical constituents of the walls seem to have been removed, with the result that conspicuous diagonal striations have been formed. The pattern is strongly suggestive of fungous erosion (Pl. II, Fig. 1). In transverse section the tracheid walls have a somewhat frayed appearance. The thin walls of the ray cells have also suffered considerably, and tangential sections show little of the ray structure. The rays can be studied quite satisfactorily, however, in radial section.

The name *Xenoxylon* was proposed by Gothan (4, p. 38) for *Pinites latiporosus* described by Cramer (3, p. 176) from the Upper Jurassic of Green Harbor, Spitzbergen. The distinguishing characteristics of the genus are: (1) large, contiguous, vertically flattened bordered pits on the radial walls of the tracheids, (2) very large pits in the cross fields, and (3) absence of pits on the horizontal and end walls of the ray cells. It was on the basis of the last of these characters that *Xenoxylon* was regarded as a member of the araucarian alliance. Opposed to this interpretation, however, are the large pits in the side walls, which are quite unknown among araucarians. The genus is thus a typical "transition conifer." It was a common and widely spread tree in northern latitudes during late middle Mesozoic times, and has been found in Spitzbergen, King Charles Land, Yorkshire, Poland, France, Germany, Korea, Manchuria,

and western Canada. Its occurrence in northern Alaska is therefore not unexpected.

A transverse section of the wood shows a series of narrow growth rings that range in width from 0.2 to 1.25 mm., averaging 0.5 mm. (Pl. I, Fig. 2). The late-wood zone is narrow, consisting usually of only one, but occasionally of two or three, cell layers. Average-sized tracheids in the broad early-wood zone are 30–45 × 40–60 microns in tangential and radial dimensions; those in the late wood have radial diameters of 12–16 microns. In shape, they show a decided tendency to rectangularity throughout the section. No resin cells are present, nor can xylem parenchyma of any kind (except ray parenchyma) be recognized. Dark material in some of the late-wood tracheids is evidently the residue from partial disintegration of the secondary walls. The rays are strictly uniseriate and narrow, scarcely exceeding 12 microns in width, and the thin horizontal and end walls are unpitted.

In the radial section the pits in the early wood are uniseriate, vertically flattened, and transversely elongate (Pl. II, Figs. 1, 3). The transverse dimensions of the pits vary from 21 to 35 microns, but the vertical measurement is rather constantly 12 microns, or close to it. The apertures are sometimes round and sometimes slightly elliptical, but rarely oblique. They are about 5 microns in diameter. An obvious feature in pit distribution is the fact that although the pits are always close together and mutually flattened, the entire radial wall of a tracheid is not pitted. The pits are in groups of from 2 to 30 or more, and the groups are separated by unsculptured wall portions from 0.02 mm. to 1 mm. high. In the larger groups the pits tend to be more compressed by each other than in the smaller ones. The cross and vertical diameters of the terminal pits in a group tend to be more nearly equal than those of the pits in the interior. No special arrangement of the pit groups (group patterns) can be made out. At some places, where the oblique striations coincide with the pit openings, the aperture looks deceptively oblique (Pl. II, Fig. 1).

An important feature that has apparently been overlooked in *Xenoxylon latiporosum* is the presence of narrow but distinct crassulae (bars of Sanio) between the bordered pits in the tracheid walls (Pl. II, Fig. 1). Because of the crowded condition of the pits, the crassulae are narrow, but in the best-preserved tracheids they

show distinctly as fine black lines about 1.5 microns wide. These structures have some bearing upon the relationships of *Xenoxylon*, because they are generally regarded as abietinean rather than araucarian characters.

The thin transverse septations in the tracheids that have been figured by Gothan (5), Ogura (12), and others, are numerous in our material (Pl. II, Fig. 3). They are present in all the tracheids, and are spaced with relative regularity at intervals of from 35 to 100 microns throughout the tracheid length. They are nearly always transverse. Ogura presents evidence of the tylosoid nature of these septations and by means of drawings shows them connected to ray cells. Although this may be the most plausible explanation of their nature, in our specimen they are present in such great numbers that connection of all of them with ray cells does not seem quite possible. Preservation of cell detail is not adequate, however, to show their exact relation to the tracheids and the ray cells.

The pits on the radial walls of the late-wood tracheids are round or squarish, with oblique openings that extend diagonally across the whole width of the radial facet (Pl. II, Fig. 2). Because of the oblique position of the slit, its length is slightly greater than the diameter of the tracheid, and, owing to their proximity, the oblique bars of wall material present a specter of tertiary spirals. That they are not tertiary spirals is shown by the fact that they do not lie directly over the pit openings, but between them.

The rays, which are 2–12 cells high, consist of thin-walled cells with pits only on the lateral walls. The ray cells are approximately 25 microns high, and seem to be of two kinds, resinous and nonresinous. The resinous cells are in continuous rows that are interspersed among rows of nonresinous cells, there being several of the latter to each one of the former. Commonly, but by no means always, there are two rows of nonresinous cells at the top and bottom of a ray, and next to them a third row composed of resinous cells. Except for their contents, there are no visible differences between the two kinds of ray cells.

The very large pits in the lateral walls of the ray cells occupy practically the entire area of the cross field (Pl. II, Fig. 3). Generally there is only one, but there may be two where an end wall lies over a cross field.

Tangential sections reveal considerable pitting in the tangential walls of the late-wood tracheids. These pits are oblique, and closely resemble those in the radial walls except for being smaller.

There are some differences between the Alaskan material of *Xenoxylon latiporosum* and the material described by Cramer (3) and by Gothan (5), but they are hardly sufficient to justify separation as species. In our specimen the pits are not quite so large: the maximum width seems to be about 25 microns, as opposed to 40 microns in the type. In addition, Cramer gives the average diameter of the tracheids in his material as 62.4 microns, whereas in ours it is slightly less. However, all previously published figures of *X. latiporosum* show striking similarities with ours in form and arrangement of both the ordinary pits and those of the ray cells.

The combination of anatomical features shown by *Xenoxylon* makes it impossible to place the genus in any existing group of modern conifers, even though araucarian affinities have been favored by Holden and other authors who have worked with it. The araucarian features cited by them are: (1) lack of resin parenchyma or resin ducts, (2) lack of pits on the horizontal and end walls of the ray cells, (3) the crowded and mutually flattened condition of the pits on the tracheid walls, and (4) the absence of crassulae.

Holden maintained that the presence or absence of crassulae is more important in distinguishing between araucarian and abietinean conifers than is the type of tracheary pitting or the occurrence or nonoccurrence of pitting on the ray cells. Although the tracheary pitting in modern araucarians is quite different from that in the Pinaceae, the same distinction does not always prevail in fossil woods. In *Brachyoxylon*, for example, both types occur, and, moreover, *Brachyoxylon* pitting is said to occur in araucarian seedlings. These examples do not disqualify pit characters as a means of distinguishing mature secondary wood of the two families of conifers, but they do show that the difference is not quite so fundamental as was once supposed. Furthermore, the criterion of whether or not the ray cells are pitted, a feature stressed by Gothan (4), is not wholly satisfactory in distinguishing fossil woods, because *Araucariopitys*, a Lower Cretaceous genus, shows tracheids with typical abietinean pits along with unpitted rays of the araucarian type.

Because pit characters are not infallible criteria for distinguish-

ing araucarian and abietinean fossil woods, Holden used the crassulae, maintaining that these thickenings in the middle lamella between pits are consistently absent from all araucarians and their relatives, both ancient and modern. Bailey (1), however, in an ably presented appraisal of anatomical features in common use for identification of Mesozoic coniferous woods, says that the absence of crassulae is by no means an absolute criterion of araucarian affinities. He points out the uncertainties of preservation, and notes that in some living woods careful differential staining is necessary to reveal these structures. Thus if too much trust is placed upon the fact that crassulae are not visible in a given instance, an abietinean would be proclaimed araucarian simply because the crassulae were not preserved or not stained.

If woods that show crassulae are positively not araucarian, as Holden maintained, we are forced to uproot *Xenoxylon* from among the araucarians and transplant it among the Pinaceae. However, the combination of characters present shows that this cannot be done with complete abandon because discovery of the crassulae does no more than subtract one of the several araucarian traits and substitute an abietinean trait in its place. There are other characters whose status remains unchanged. Considerable confusion and misunderstanding about the affinities of fossil conifers has resulted from an "either-or" attitude on the part of investigators who have endeavored to force misfits into modern families where they do not belong. *Xenoxylon* is an example of a fossil conifer that cannot be placed with positiveness in any modern family, and an arbitrary disposition of such woods only causes confusion.

Although there is no direct evidence of a connection between the wood and the other organs in the material under consideration, it may be noted that foliage of both *Podozamites* and *Baiera* is abundant at the place where it was found. Foliage of members of the Taxaceae is also present, but affinity with this family is not probable.

Horizon.—Chandler formation of the Nanushuk group, Lower Cretaceous.

Locality.—"Big Bend" of the Colville River, three miles south of the mouth of the Awuna River, Naval Petroleum Reserve No. 4, Alaska.

Cedrus alaskensis, sp. nov.

(Pl. I, Figs. 1 and 3; Pls. III and IV)

The specimen described here is a piece of secondary wood from the outer part of a silicified trunk embedded in sandstone above a three-foot seam of coal.

A transverse section shows a series of well-marked growth rings that range from 2 to 4 mm. in width. The early-wood zone is much wider than that of the late wood, and is made up principally of rectangular and hexagonal tracheids that measure 40–50 × 55–90 microns. In many of the tracheids the tangential walls are conspicuously thicker than the radial walls (Pl. IV, Fig. 2). During the process of partial degradation of the walls previous to silicification, the middle lamella and the primary layers disintegrated to a greater extent than did the apparently more strongly lignified secondary walls. The result is that in the thin sections narrow open spaces appear within the tangential wall complexes.

A few vertical resin ducts show in the transverse section. Some resemble the so-called normal type, but others are evidently the result of injury to the cambium.

The normal ducts are rare, only five being present in a section that measures 3 × 4 cm. They can consequently be easily overlooked, and in small wood fragments might not be present at all. Regardless of their scarcity, however, they are important from the standpoint of identification. The normal vertical ducts are considerably larger than the horizontal ducts (Pl. III, Figs. 1–2). The resin cavity is surrounded by a layer, one or two cells deep, of epithelial cells with slightly thickened walls and numerous pits.

The traumatic ducts occur both singly and in short arcs in the late wood (Pl. III, Fig. 3). Their cavities are similar in size to those of the normal ducts, and are surrounded by cells with similarly thickened walls. These ducts, too, are rare, only one short arc about 2 mm. long and a few isolated ducts occurring in the section 3 × 4 cm. large mentioned above.

All the rays except those containing horizontal ducts are narrow and have minute but distinct pits on the horizontal walls of the cells.

The horizontal resin ducts are long: in one instance a duct can be followed across seven growth layers. They are flanked by one or two layers of parenchyma cells that resemble ordinary ray paren-

chyma in wall characteristics and in pitting (Pl. IV, Fig. 4). Sometimes these ducts terminate abruptly at the outer limit of the late wood of a growth ring, with ordinary tracheids replacing them in the second ring. Connections between the horizontal and the vertical ducts can be observed in a few places, but it is uncertain whether all of the horizontal ducts arise from vertical ducts.

In radial section the pits on the walls of the late-wood tracheids are round, uniseriate, and distantly spaced. In the early wood they are mostly biseriate and opposite (Pl. I, Fig. 3; Pl. IV, Fig. 1), although the uniseriate and triseriate conditions may occasionally be observed. The pits vary from well separated to crowded. There is a tendency at places for the pits to be clustered into small groups of from 2 to 4 (Pl. IV, Fig. 3). Where separated, the pits are round, but the more crowded ones show slight flattening or angularity. The diameter of the pit cavity is about 21.5 microns, and the conspicuous torus is about 7–8 microns. The aperture is circular in all pits. Crassulae about 2 microns wide are present wherever the pits are close together (Pl. I, Fig. 3).

The ray cells are all parenchymatous, measure about 17 microns high, and have oblique ends. They are pitted on all walls—abundantly on the horizontal and end walls, but sparsely on the lateral ones. Each cross field has 2–4 small circular pits about 6 microns in diameter (Pl. I, Fig. 3).

In tangential section the simple uniseriate rays are narrow and very small—only about 12 microns wide and 2–30 cells high, the average being about 12 cells (Pl. III, Fig. 2; Pl. IV, Fig. 5). The triangular intercellular spaces show between the corners of the ray cells and the adjacent tracheids (Pl. IV, Fig. 5). Occasionally blind pits directed toward the intercellular spaces are visible.

The horizontal resin ducts are smaller and more numerous than the vertical ones. In one tangential section measuring 1.3 × 4 cm., eighty-seven ducts were counted. Although the ducts occur throughout the section, they tend to be somewhat patchy in distribution. There are places where as many as six can be seen within the bounds of a microscopic field 4 mm. in diameter; at other places none occur within an area of that size. It is impossible to see how these could all be connected with vertical ducts, because the latter are so scarce.

Pitting of the tangential walls of the tracheids appears to be

limited to the outermost row of late-wood tracheids and then mostly to the outermost wall. On this wall a few small scattered pits can be seen. Tangential pitting is not a conspicuous feature in this wood.

In the wood under consideration the most important anatomical characteristics may be summarized as follows:

1. Conspicuous growth rings, with thin late-wood layers
2. Scattered normal and traumatic vertical resin ducts
3. Numerous horizontal resin ducts
4. Walls of cells surrounding resin ducts pitted
5. Tangential walls of tracheids thicker than radial walls
6. Predominately opposite, occasionally semiclustered, arrangement of pits on radial walls of tracheids
7. Large torus
8. Distinct crassulae between pits
9. Absence of ray tracheids
10. Ray cells pitted on all walls
11. From 2 to 4 small circular pits in each cross field
12. Sparse tangential pitting

The combination of anatomical characters listed above is more indicative of *Cedrus* than of any other genus of conifers, either living or extinct. The presence of apparently normal vertical and horizontal resin ducts immediately suggests affinity with *Pinus*, *Picea*, *Larix*, and *Pseudotsuga*, but these are all eliminated for one reason or another. *Pseudotsuga* is out of consideration because of the absence in the fossil of tertiary spirals in the tracheids. The pitted walls of the epithelial cells and the predominately biseriate pitting are contrary to what one finds in *Pinus*. There is no point in making detailed comparisons with *Picea* or *Larix* because of the lack of ray tracheids, the character of the pitting, and other features.

Although *Cedrus* is said to lack normal vertical resin ducts (Jeffrey, 9; Penhallow, 13), isolated ducts showing no visible differences from so-called normal ducts do occur. Living species have ray tracheids, which are lacking in the fossil material; but they are also lacking in *C. penhallowii*, a fossil species from the Miocene (Barghoorn and Bailey, 2). Except for the absence of ray tracheids in *C. alaskensis*, the structure of the rays is almost identical with that in

modern species, the similarity extending to the occurrence of blind pits directed toward the intercellular spaces. The most evident features, however, pointing to *Cedrus* are the distribution of the pits on the radial walls of the tracheids, the large conspicuous tori, the presence of prominent crassulae between adjacent pits in vertical series, and the pitted epithelial cells. Biseriate opposite pitting is the rule throughout the broad early-wood zone, but multiseriation occurs occasionally. In the transition from early to late wood, where the tracheids begin to narrow, biseriation gives way to uniseriation, and it is in this zone that the slight tendency toward grouping and sometimes toward partial alternation is observed. In this transition zone the pits in some tracheids are widely separated and the crassulae disappear (Pl. IV, Fig. 3). The tendency toward alternation is never pronounced, and no special importance can be attached to it. Similar situations, however, have been noted in living species.

The problem of choosing suitable generic names confronts every investigator working with Mesozoic woods, and often the dilemma can be met only by describing new genera. The result has been that practically every author who has described Mesozoic woods has one or more generic names to his credit, and the tendency to set up new genera increases as time goes on. In the old days names like *Pinites* and *Pitus* were applied without much discrimination, but paleobotanists become more discerning as they learn more about living coniferous woods. Because of the necessity of drawing fine distinctions between fossil genera, the number is large. Kräusel (10) listed more than seventy in 1919, and additional ones have subsequently been named. Only a small share of these, however, have been described in sufficient detail to render them usable.

Bailey (1) has endeavored to simplify the situation with respect to abietinean-wood nomenclature by reducing the number of generic names to three, each one embracing those fossil woods that fall within the structural range of a particular genus or group of genera. Thus *Pinuxylon* includes those woods that come within the structural range of *Pinus*. *Piceoxylon* embraces those within the structural range of *Picea*, *Larix*, and *Pseudotsuga*, and *Cedroxylon* is the fossil counterpart of the woods of the *Keteeleria*, *Pseudolarix*, *Cedrus*, *Tsuga*, and *Abies* types. Several fossil genera would also be included under *Cedroxylon*.

In regard to the fossil wood under consideration here, the peculiar situation exists that the fossil genus *Cedroxylon* is not so appropriate for it as is *Cedrus*. *Cedroxylon*, as commonly defined, lacks vertical ducts (except for traumatic ones) and has ray tracheids, a situation largely reversed in our fossil. Furthermore, the resemblances to *Cedrus* are more exact in other respects. If a fossil epithet were to be used, the most suitable one would probably be *Pityoxylon*, which would merely denote affinity with the Pinaceae. *Cedrus alaskensis* differs from the modern species of the genus in lacking ray tracheids, thereby resembling *Cedrus penhallowii* from the Miocene (Barghoorn and Bailey, 2).

Wood identified as *Cedroxylon* has been reported several times from the Arctic in rocks ranging from Jurassic to Tertiary (Gothan, 5; Høeg, 7; Seward, 14; Walton, 15; Mathiesen, 11). The wood from the Colville River in northern Alaska, however, is not only the first instance of the occurrence of the genus *Cedrus* in Alaska, but apparently constitutes the oldest record of wood more appropriately referable to that genus than to *Cedroxylon*. Lack of ray tracheids appears to be the main difference between it and modern species. Three species of *Cedroxylon*, *C. greenlandicum* (Walton, 15), *C. orvini* (Høeg, 7), and *C. nordenskjöldi* (Mathiesen, 11), have been described from Greenland, but from formations believed to be of Tertiary age. None of them are identical with *Cedrus alaskensis*. *Cedroxylon greenlandicum* has vertical wood parenchyma interspersed in the late wood, and horizontal resin ducts are not mentioned in the description. *Cedroxylon orvini* also has vertical parenchyma; it differs further from our species in having a few marginal-ray tracheids. The regular tracheid pits are uniseriate, and horizontal resin ducts are apparently lacking. *Cedroxylon nordenskjöldi* appears to be based on root wood. It resembles *Cedrus alaskensis* rather closely in pit characteristics and in having horizontal ducts. It differs, however, in its rather numerous ray tracheids. *Cedrus alaskensis* is probably closer to *Cedrus penhallowii* than to any of the Arctic species of *Cedroxylon*, the main difference between the two being the crystal-bearing cells along the margins of the rays in *Cedrus penhallowii*.

Horizon.—Presumably the Nanushuk group, Lower Cretaceous.

Locality.—Right bank of the Oolamnagavik River at its junction with the Colville River, Naval Petroleum Reserve No. 4, Alaska.

I wish to express my appreciation to Dr. E. S. Barghoorn, who examined sections of *Cedrus alaskensis* and gave me his opinions concerning its relationships.

University of Michigan

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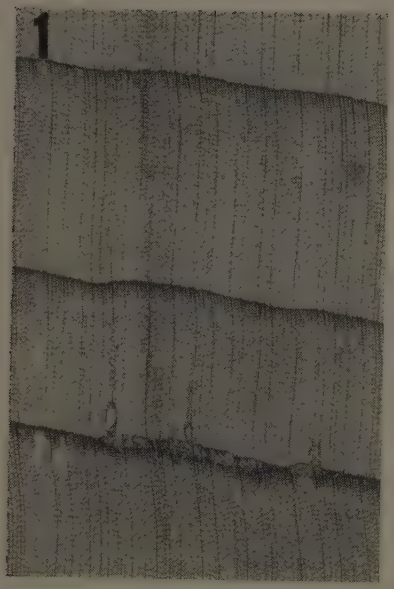
PLATES I–IV

EXPLANATION OF PLATE I

FIG. 1. *Cedrus alaskensis* Arnold, sp. nov.: transverse section showing growth rings and arc of traumatic resin ducts. × 10

FIG. 2. *Xenoxylon latiporosum* (Cramer) Gothan: transverse section showing narrow growth rings. × 10

FIG. 3. *Cedrus alaskensis* Arnold, sp. nov.: radial section showing small circular pits in the cross fields and biseriate opposite pitting and crassulae in the tracheid walls. × 220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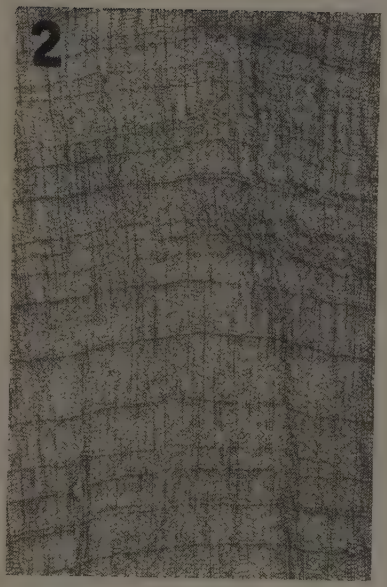
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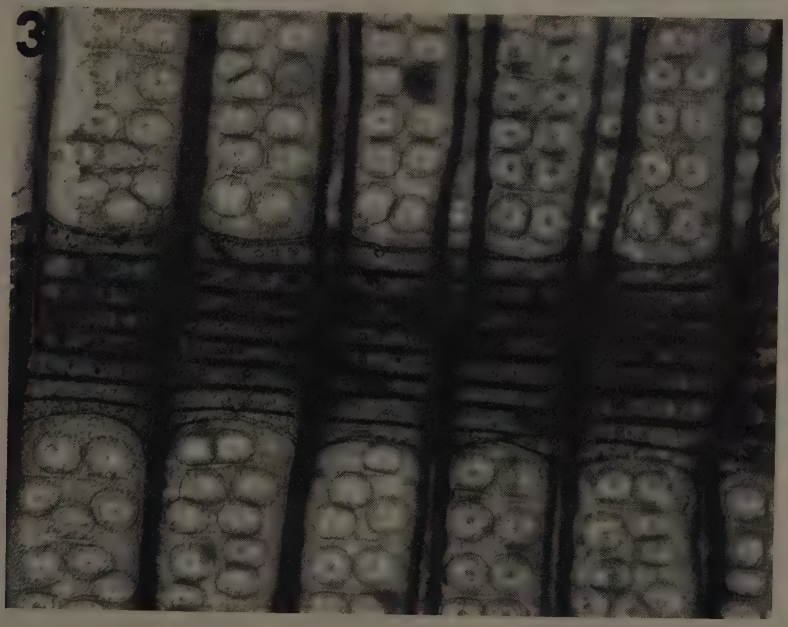
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EXPLANATION OF PLATE II

Xenoxylon latiporosum (Cramer) Gothan

FIG. 1. Radial section showing the crowded and flattened pits separated by crassulae, and unpitted portions of tracheid walls. × 490

FIG. 2. Radial section showing oblique pit apertures in narrow late-wood tracheids. × 490

FIG. 3. Radial section showing character of pitting in tracheids, septa in tracheids, and large cross-field pits and resin cells in rays. × 100

1

2

3

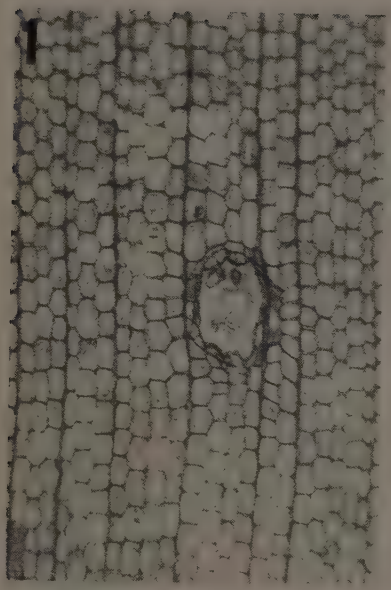
EXPLANATION OF PLATE III

Cedrus alaskensis Arnold, sp. nov.

FIG. 1. Transverse section showing normal resin duct. × 70

FIG. 2. Tangential section showing two horizontal resin ducts. × 70

FIG. 3. Transverse section showing portion of arc of traumatic ducts in late wood. × 70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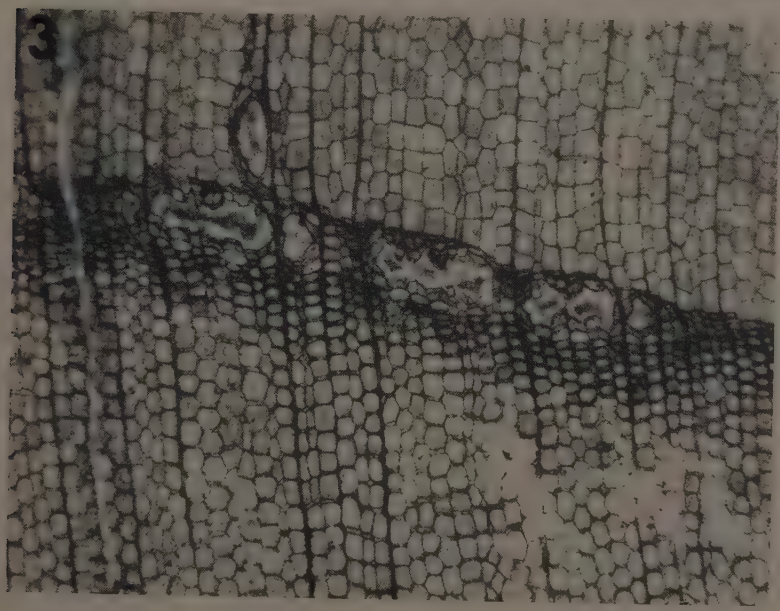
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EXPLANATION OF PLATE IV

Cedrus alaskensis Arnold, sp. nov.

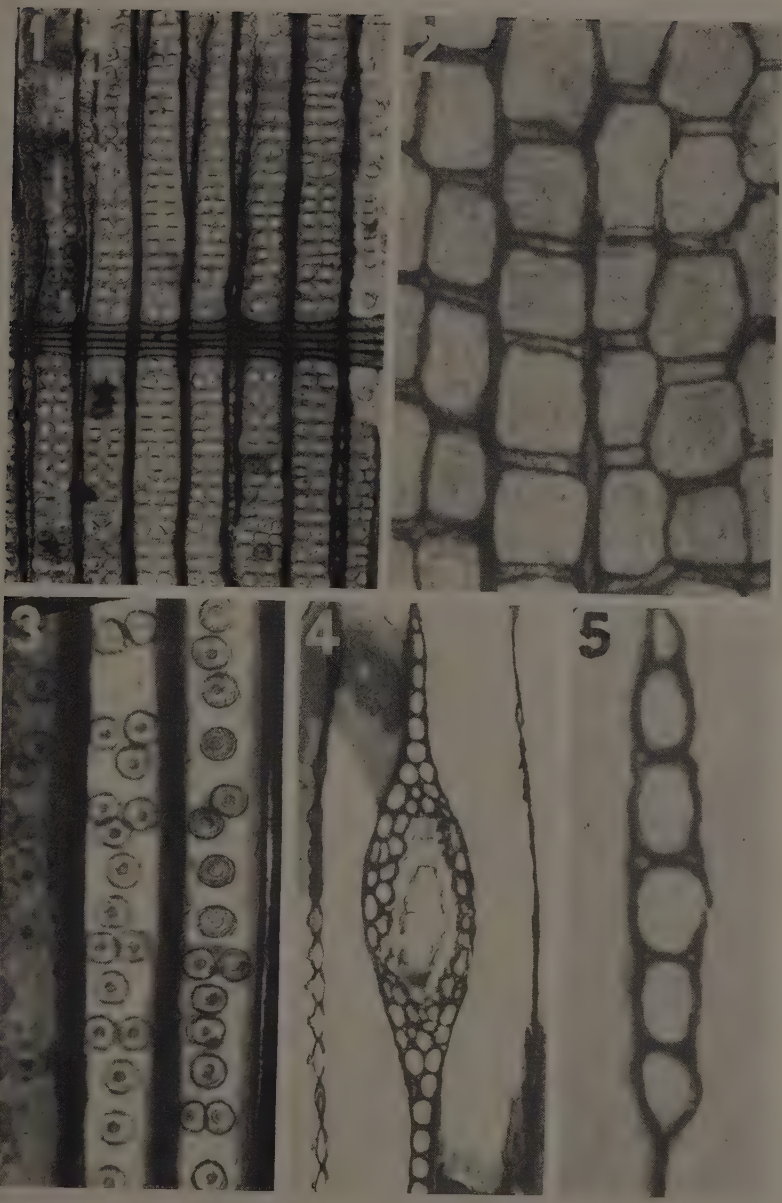
FIG. 1. Radial section showing distribution of pits. × 100

FIG. 2. Transverse section showing difference in thickness of radial and tangential walls. In the tangential walls the middle lamella and primary wall layers have mostly disappeared. × 250

FIG. 3. Radial section in transition region from early to late wood showing tendency toward alternation and clumping into small clusters. × 185

FIG. 4. Fusiform ray containing horizontal resin ducts in tangential section. × 250

FIG. 5. Tangential section of an ordinary ray showing secondary wall thickening and intercellular spaces. × 700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VASCULAR DEVELOPMENT IN THREE COMMON GOLDENROD GALLS*

JOHN L. BLUM

THIS paper summarizes structural differences, especially in regard to vascular anatomy, between three common monothalamous stem galls of *Solidago spp.*, those produced by the moths *Gnorimoschema gallaesolidaginis* Riley and *Eucosma scudderiana* Clem.[1] and by the fly *Eurosta solidaginis* Fitch. Certain facts pertaining to the life history of these insects and the structure of the galls have been worked out by Brodie (1909) and Cosens (1912). Beck (1947, 1949) has reported in considerable detail on the structure of the *Eurosta* and the *Gnorimoschema* galls, as well as on experimental work of fundamental importance to the problems of gall initiation.

The galls described in the present paper were collected, mostly from *Solidago canadensis* L., at regular intervals during the growing seasons of 1947 and 1949 in vacant, weed-covered lots in Buffalo, New York. Part of the material was prepared for study by standard paraffin methods. The remainder, intended for use in examining the effects of parasitism on the parts of the stem above and below the gall, was sectioned freehand, stained quickly, and immediately studied in a water mount. It was necessary in the course of this work to make cell counts and measurements at numerous successive levels on the stem as far as thirty-five internodes above or below the gall, and the freehand method was adopted because of the variability in the vertical extent of the changes due to parasitism in different gall-bearing stems, and because it is impracticable to embed and section long pieces of stem. The freezing microtome was tried but abandoned when it was found that better sections were obtained more easily by the freehand method.

The phrase "base of the gall" in this paper refers to the lower-

* The research for this paper was done while the author was on the staff of Canisius College, Buffalo, New York.

[1] *Epiblema scudderiana* (Clem.) in the newer classification.

most level on the stem at which enlargement due to the gall is externally visible. "Top of the gall" refers to the uppermost level at which enlargement is externally visible. These two levels arbitrarily define the extent of the gall and, taken together, are here

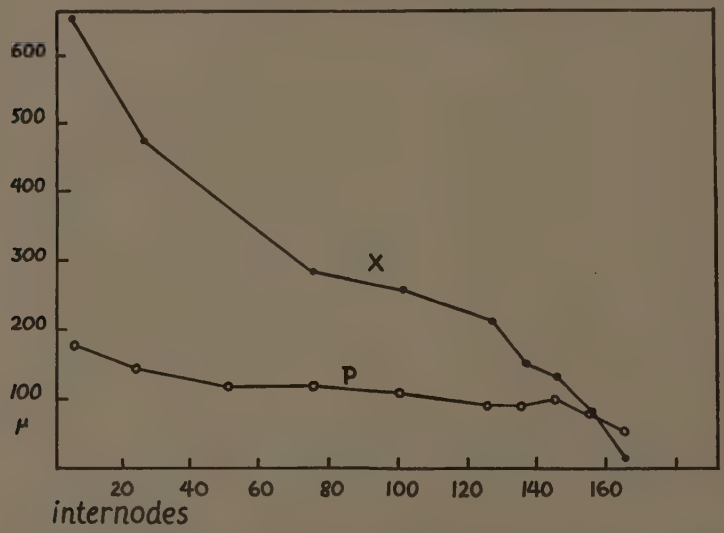

Fig. 1. Curves showing relative amounts at end of growing season of secondary xylem (*X*) and total phloem (*P*) at different levels in a normal Solidago stem. Each point here and in Figures 3, 4, and 5 represents an average of the maximum radial dimensions of ten consecutive vascular bundles.

called the "limits" of the gall. It is to be emphasized that the larval cavity may extend beyond these levels both above and below the gall, and that the histological effects of parasitism may likewise be noted at some distance beyond the limits of the gall as thus defined.

Structure of the Normal Stem

The normal erect stem of *Solidago canadensis* grows from the rhizome in early spring and in about eight weeks produces from seventy to one hundred internodes before any major branches are formed. The first twenty-two internodes (approximately) have an

average length about twice that of the upper internodes, most of which are from 1 to 10 mm. long. The branches bear the inflorescence; they are formed late in summer in the axils of from ten to thirty of the uppermost leaves. Normal stems of the species forming the galls studied here vary from 2 to 9 mm. in diameter, and in cross section show about twenty-five to forty vascular bundles. Secondary thickening begins at a level about five internodes below the terminal bud and remains moderate in amount throughout most of the length of the mature stem, but increases sharply in the lowermost five to ten internodes (Fig. 1). Details of the histology of the normal stem have been described by Beck (1947).

The Gnorimoschema Gall

In western New York the *Gnorimoschema* galls become evident on the young goldenrod stem in late May or early June, mostly in the region between the fifteenth and the thirty-fifth nodes. The young larva grows rapidly within a vertical cylindrical or fusiform cavity which it cuts in the pith. As it develops, the middle portion of the cavity enlarges from four hundred to five hundred per cent by the outward distention of the remaining stem tissues, namely the vascular cylinder and the tissues external to it. This is apparently brought about by the proliferation and enlargement of cells adjacent to the vascular tissues in both the cortex and the pith. The maximum outer dimensions—about 1.5 cm. in diameter and 8 cm. in length—are attained by late July, but many *Gnorimoschema* galls never reach these proportions. Little change in the gall tissues takes place after this time. The thickness of the wall of the mature gall may be only from one quarter to one third of the radius of the gall.

The number of the vascular bundles is greater (from fifty to eighty) in the middle portion of the mature gall than in the normal stem, but the number of bundle caps remains the same as in the normal stem. This increase in the number of vascular bundles is brought about mostly by proliferation of the xylem parenchyma and by differentiation of new vascular elements in ray derivatives. Cells of certain of the rays, often every third or fourth one, are stimulated to divide repeatedly. As the cells thus formed enlarge, they are pushed in the direction of the center of the stem by the similar proliferation and growth of the endodermis and of the cor-

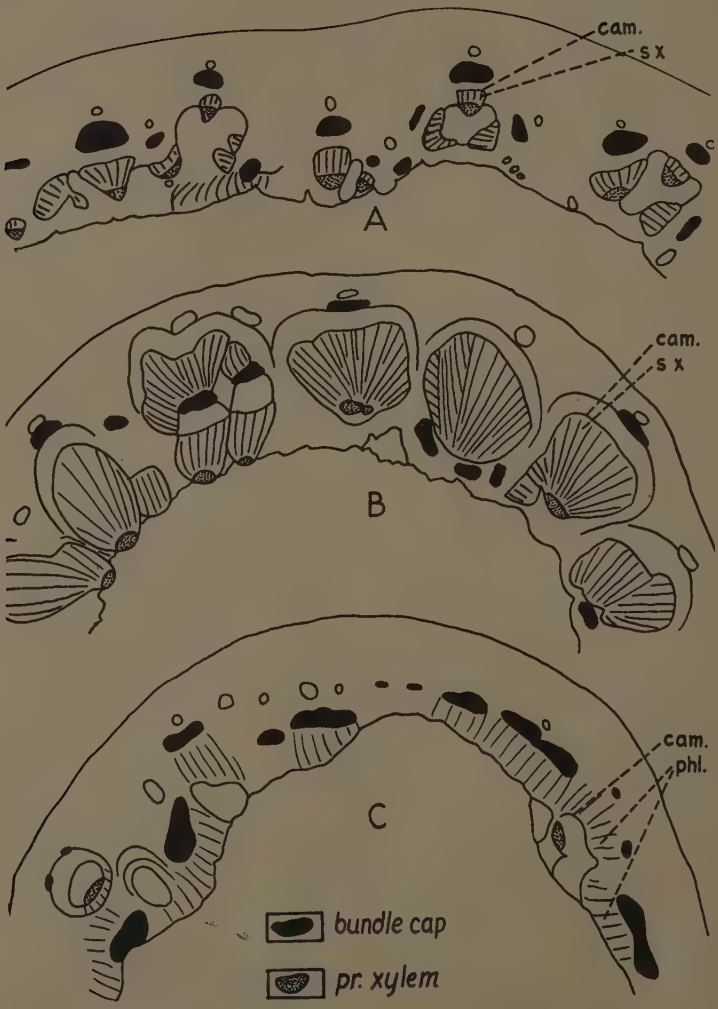

FIG. 2. A: *Gnorimoschema* gall, cross section of a portion of the wall; circular or oval areas external to the bundle caps on this and the two subsequent figures represent resin ducts; *cam.* indicates the cambium; *sx*, the secondary xylem; unshaded areas surrounded by xylem groups represent small masses of unchanged pith

tical parenchyma immediately external to the rays, as well as by the growth of the ray tissue itself. Once this parenchymatous tissue has penetrated to a point internal to the vascular cylinder, its edges fan out somewhat and in many places may join a similar tissue formed by the internally directed proliferation of the remaining cells of the outermost region of the pith and of adjacent cells of the xylem parenchyma. This internally directed growth provides the larval cavity with a lining of small, proliferating cells. When the gall reaches maturity, these cells develop scalariform lignified thickenings (Beck, 1949) and, along with the vascular bundles, give the gall a woody character which better adapts it to the protection of the pupa. Erosion of the gall tissue by the maturing larva may extend from the pith outward to the xylem parenchyma, but does not usually include any conducting elements of the xylem.

It is noteworthy that many of the rays do not become meristematic. Three or four of these inactive rays usually occur together in a short series, in which they alternate with as many vascular bundles. After the proliferation of the rays flanking such regions on either side, the bundle caps and the outer tissues of the vascular bundles nearest to the proliferating rays act as if they were being pulled along by the proliferating cells as these cells migrate in a centripetal direction, with a resulting declination of the original radial plane of these vascular bundles away from the plane of the central bundle in the nonproliferating series (Fig. 2A). This declination approaches the tangential plane in some of the vascular bundles; in others it may surpass the tangential and result in an almost inverted bundle. The vascular bundles are thus separated into groups of from three to five bundles, of which one, often the largest of the group, retains its original orientation while the others become more or less inverted, the xylem side of each bundle being directed approximately toward the center of the incomplete circle described

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Explanation of Figure 2, continued

cells. B: *Eucosma* gall at end of growing season, cross section of wall near middle of gall; parallel lines indicate orientation of rows of cells in the secondary xylem and in the xylem-like tissue formed anomalously in the cortex. C: *Eucosma* gall in midseason, cross section of the wall near the upper end of the gall; *phl.* indicates the phloem; parallel lines indicate orientation of rows of cells in the phloem.

by the cambium, which is folded toward the outside at this point. In this way the cambium, which is ordinarily a cylinder with nearly smooth sides, becomes vertically corrugated.

A group of vascular bundles thus organized in the wall of the *Gnorimoschema* gall forms the outer and the lateral boundaries, or sometimes the complete boundary, of an island of pith cells which appear entirely unchanged in size and shape and may not even divide. Generally, the internal boundary of this mass of pith cells is the internal proliferating layer of the larval cavity itself.

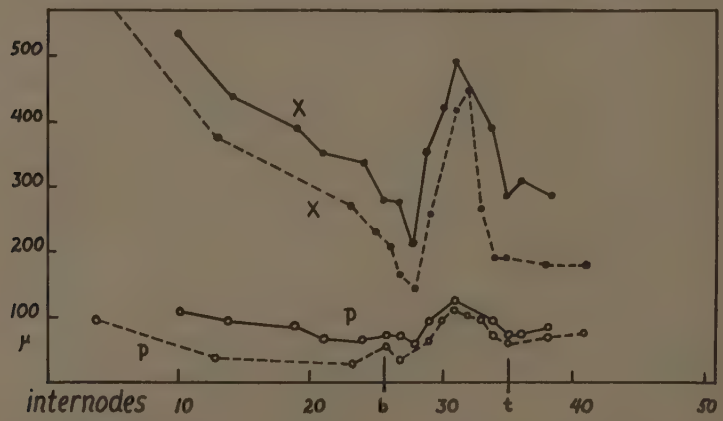

FIG. 3. Curves showing relative amounts at end of growing season of secondary xylem (*X*) and total phloem (*P*) at different levels in two Solidago stems each bearing a gall of *Gnorimoschema* in internodes 26–35; *b*, base of gall; *t*, top of gall; solid line represents plant 1; broken line, plant 2.

Among the most interesting effects of parasitism are the changes brought about in cambial activity. At the level on the stem where the gall is found, cambial activity is relatively slight up to the time of gall initiation. After infestation by the larva, the cambium in the middle region of the gall is stimulated to form secondary tissues comparable in amount to those present in the older parts of the stem approximately twenty internodes below the gall. Maximum cambial activity here seems to occur at the level of maximum anomaly in stem histology and of maximum activity of the larva (Fig. 3). The growth of the cambium of the lower portions of the

gall is, however, clearly inhibited, with a consequent production of secondary xylem that falls far short of what is found only one to one and one-half centimeters below, in the presumably unaffected parts of the stem. This inhibition is clearly seen in the xylem region. Probably because of the relatively narrower band of secondary phloem visible in the cross section and because of the difficulty of distinguishing clearly the secondary phloem from the primary, the inhibitory effect is not evident in the external derivatives of the cambium.

The Eurosta Gall

The development and histology of the *Eurosta* gall and the biology of its parasite have been worked out very carefully by Beck (1947) and will not be repeated in detail here.

In western New York the *Eurosta* gall is initiated in mid-June. Its growth is extremely rapid and results in a massive parenchymatous structure occupying approximately the region of the eightieth node and composed mostly of pith derivatives. Much of this growth depends upon divisions within anastomosing meristematic strands which are directed from the surrounding vascular cylinder toward the relatively small cavity of the larva. Cosens (1912) refers to these meristematic strands as "vascular strands" thus imputing to them the function of conduction toward or away from the larva. This view is supported by the peripheral origin of the strands immediately adjacent to the primary xylem, by the staining of such strands when the freshly cut stems are placed in solutions of eosin, and by the fact that at least certain of the cells in the strands mature into scalariform-reticulate elements, although perhaps the majority do not.

Though the stem is stimulated by the presence of the parasite to the production within the pith of tracheid-like cells, no such effect is evident in adjacent regions of the vascular cylinder, where there is, instead, a sharp reduction of cambial activity in the middle portion of the gall (Fig. 4). In the upper part of the gall, however, an increase in cambial activity can be noted; it reaches its maximum just at or slightly above the upper limits of the gall, from which point secondary tissues decrease gradually in amount, so that it is difficult to determine just how far above the gall the stimulation of the cambium is felt. Thus the region of larval activity and of

maximum anomaly within the stem here coincides with the region of maximum depression of cambial activity, in sharp contrast to the condition in the galls of *Gnorimoschema* described above.

The reduction in the amount of xylem in the vascular bundles within the gall supports the theory of the vascular nature of the derivatives of the meristematic strands, and suggests an enhanced ability on the part of these strands to obtain some necessary growth factor when in competition with the cambium.

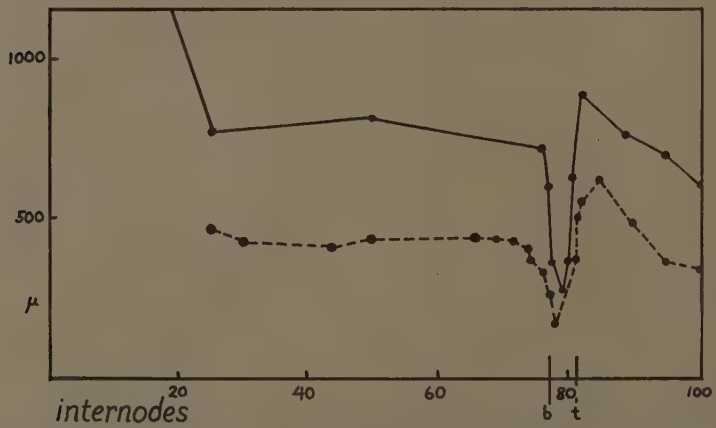

FIG. 4. Curves showing relative amounts at end of growing season of secondary xylem at different levels in two Solidago stems each bearing a gall of *Eurosta* in internodes 76–81; *b*, base of gall; *t*, top of gall

THE EUCOSMA GALL

In western New York the *Eucosma* gall develops on goldenrod stems in early or mid-July. It is formed at approximately the one hundredth internode. Its structure has been described briefly by Cosens (1912). Infestation of the pith and destruction of its cells by the parasite are followed by greatly accelerated cambial activity. In later growth, secondary thickening is extremely marked within the limits of the gall; it gradually decreases both above and below the gall to the limited amount expected in a normal stem in the upper internodes, although the effect of augmented cambial activity may be observed as much as three internodes below the

gall (Fig. 5). As in the *Gnorimoschema* gall, the region of maximum stem anomaly here corresponds with the region of maximum stimulation of the cambium, although the area of greatest anomaly is especially characteristic of the upper portion of the gall. The most marked destruction of gall tissue likewise occurs in the upper half of the gall. There is no apparent region of cambial inhibition such as is evident in the other two galls considered.

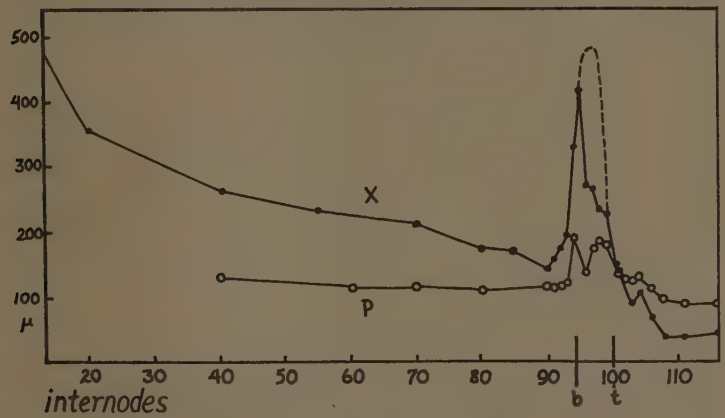

FIG. 5. Curves showing relative amounts at end of growing season of secondary xylem (*X*) and total phloem (*P*) at different levels in a Solidago stem bearing a gall of *Eucosma* in internodes 94–100. Broken line indicates estimated amounts of secondary xylem which would be present if none of it had been eroded by the larva.

Enlarged cortical resin ducts are characteristic of this gall, a condition recalling the extensive resin-duct formation in the pith of the *Eurosta* gall.

In many, but apparently not all, *Eucosma* galls the cortex is responsible for much of the abnormal growth. Early in the development of the basal part of the gall, arcs of cells in the endodermis and the inner part of the cortical parenchyma lateral to the bundle caps, and, later, between the resin ducts and the pericycle, may cut off xylem-like derivatives to the inside and phloem-like derivatives to the outside (Fig. 2B). Depending on the degree of curvature of the arc, the cortical mass of xylem-like cells may be partly or completely surrounded by such an embryonic layer, which cuts off its

own internal derivatives from two or more sides but especially from the outer side, thus forming what appear to be, in effect, collateral and amphicribral bundles. Apparently as a result of the growth of this embryonic layer, a portion of the vascular bundle internal to such a mass of cortical cells is thrust inward into the larval cavity, and eventually is consumed in whole or in part by the larva. The mass of xylem-like cells of the cortex meanwhile increases mainly on its outer face by divisions within the cambium-like layer from which it has been derived and comes to occupy the former position of the displaced primary vascular bundle at this level.

Since such cortical growth takes place for the most part adjacent to alternate bundles rather than next to all bundles, the vascular equipment of many of the mature galls consists of bundles of stelar primary and secondary tissues alternating with the anomalous bundles of cortical derivation (Fig. 2B), which simulate, except for the absence of a bundle cap, the original vascular bundles with their added secondary tissues. The bundle caps can frequently be found internal to the cortical bundles on the same circumference within the stem as any groups of primary xylem of the flanking, true bundles which may have escaped ingestion by the larva. The resulting corrugation of the cambial cylinder approximates the condition in the *Gnorimoschema* gall, except that the vascular bundles here are left essentially single rather than in scattered groups and except that the true cambium, as well as all tissues internal to it, may be eroded away completely by the *Eucosma* larva at any point where the cambium folds in toward the larval cavity.

The bundles thus formed within the cortex appear to develop acropetally, starting at the base of the gall. For a time in the early stages the feeding of the larva upon the vascular tissue may leave, at least in the upper levels of the gall, little if any connection between the xylem of the lower stem and that of the stem above the gall (Fig. 2C). This condition is apparently corrected later by the formation of the cortical bundles, which establish a partial bridge between the vascular tissues of the lower section of the stem and those of the upper section. The xylem of at least some of the true vascular bundles connects directly with the xylem-like cells of the cortical bundles, but the upper and lower parts of others of the cortical bundles appear to end blindly in the cortex.

Another peculiarity of the *Eucosma* gall is the tendency of ad-

jacent pith cells both above and below the gall to become thick-walled. This effect is evident for not more than about 7 mm. beyond the limits of the gall. It is an interesting response in view of the fact that the pith is not generally reactive in the *Eucosma* gall and takes virtually no part in gall formation, although a few divisions are often observed within remaining pith cells.

Discussion and Summary

It is remarkable that the effects of insect infestation of a single kind of plant can result in such diverse histological structures. *Gnorimoschema gallaesolidaginis* forms a relatively thin-walled gall in which the cambium cylinder is corrugate because of the internally directed proliferation of some, but not all, of the rays. A proliferating layer of small cells develops from the ray tissue and the xylem parenchyma internal to the vascular cylinder. Cambial activity is clearly stimulated in the middle and upper portions of the gall, and sharply inhibited in a small portion of the gall near its basal end.

In the gall caused by *Eurosta solidaginis*, responses to the gall stimulus occur mainly in the pith, and consist of rapid cell divisions and the extensive development of anastomosing resin ducts and meristematic strands. The normal activity of the cambium in the major part of the gall is almost entirely inhibited, but this inhibition is sharply reduced immediately above the gall, where a slight increase of cambial activity is evident.

In the smaller gall made by *Eucosma scudderiana*, the abnormal growth is due to greatly stimulated secondary thickening and to the formation of additional bundle-like units in the endodermal area external to certain vascular bundles. The larva ingests the primary and secondary vascular tissues of all kinds and may sever nearly all of the original vascular connections between the lower and the upper parts of the stem. The walls of the pith cells immediately above and below the gall become markedly thickened.

The diversity of the plant responses here summarized suggests the presence of numerous diffusing substances which control the growth of the plant tissues. The quantitative differences in secondary thickening might be interpreted as due to variations in amount of a single controlling substance, but the pronounced tendency toward acropetal responses in one gall and toward basipetal re-

sponses in another argues against such an interpretation. The clear-cut qualitative differences between the reactions of the various tissues, especially of those at some distance from the larva, when one kind of gall is compared with another, would likewise appear to be dependent upon a variety of determining substances, as well as upon a mechanism for localizing their action with some precision in certain parts of the cylinders occupied by each of the affected tissues.

University of Michigan

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THE DATES OF PUBLICATION OF THE VOLUMES OF THE ANNUAL *REPORT* AND THE *PAPERS* OF THE MICHIGAN ACADEMY

ROGERS McVAUGH

BIOLOGISTS now universally accept the convention that the valid scientific name of any organism is the one which has priority of publication over all other names for the same organism. For correct nomenclature in biology, therefore, it often becomes important to determine the exact date of first publication of a given name. Publication is defined as the actual distribution, to the public, of printed material. Because of the delays incident to printing, binding, wrapping, and mailing, the date of distribution of a book or journal may be months or even years later than the date printed on the title page. Many biological journals, especially those which regularly publish new scientific names, now state in each issue the exact date of publication of the preceding issue. In dealing with journals which do not follow this practice, or with volumes which are issued individually, the biologist often needs to resort to indexes, reviews, accession records of libraries, and other contemporary sources in order to determine the actual publication date of a particular name.

The present paper is the result of an attempt to fix the dates of issue of the first twenty-two volumes of the *Report of the Michigan Academy of Science* and the succeeding thirty-five volumes of the *Papers of the Michigan Academy of Science, Arts, and Letters*. The *Papers*, fortunately for our purpose, have all been copyrighted by the University of Michigan, and the dates of publication, as stated in the records of the Copyright Office of the United States of America, are known. A list of these, with some remarks, is given later. The volumes of the *Report*, on the other hand, were not copyrighted, and it has been necessary to determine the dates of issue in other ways.

The Michigan Academy of Science was organized in 1894. The first meeting was held in December 1894 and the second in Decem-

ber 1895. At that time it was agreed to hold "the next winter meeting" during the spring vacation of the public schools of the state in 1897. Beginning with the third meeting, in March 1897, the Academy has met regularly each year, except 1914 and 1945, at about the same time in the spring. The first published *Report* of the Academy bears the date 1900 and covers the period from its organization in 1894 to June 30, 1899. Each succeeding *Report* covers a single year, and, beginning with the eighteenth report, the volume is entitled *Annual Report*.

Because the meetings were held early in the year (in March or early April) and because the volumes were small, it was often possible to have a report published in that same year. The tenth volume, for example, which is the *Report* for the meeting of 1908, apparently was distributed early in November of that year. A copy was catalogued by the General Library of the University of Michigan on November 2, 1908. The date 1908 appears on the title page, and there is every evidence that this date is correct. The manuscript for this volume was submitted to the governor of Michigan by the secretary of the Academy on May 28, 1908, and it accordingly seems that about five months elapsed between the receipt of the manuscript and the issuance of the completed volume.

Certain volumes, however, appear to have been issued during the year following that given on the title page, or even later than this. The seventeenth *Report*, for example, was transmitted to the governor under date of November 1915. The date on the title page is 1916, but the volume was not distributed until July or August 1917. The eighth and ninth volumes of the *Report* are not dated at all, except for the letters of transmittal, which are dated May 1, 1906, and August 31, 1907.

The *Report* was issued each year by the state,[1] and the general procedure seems to have been about as follows: After the manuscript had been submitted to the governor by the secretary of the Academy, the entire report was printed for general issue. In addition, separate copies of individual articles were struck off for the personal use of the authors. These separates were sent at once directly to the authors, generally before the work on the bound

[1] Eugene S. McCartney, "The Beginnings and Growth of the Michigan Academy of Science, Arts, and Letters," *Pap. Mich. Acad. Sci., Arts, and Letters*, 19: 12–13. 1934.

volumes was finished. The complete *Report*, once assembled and bound by the printers, was turned over to the General Library of the University of Michigan, at Ann Arbor, for distribution to the public. The Library offered the volumes in exchange or for sale. Its records (available only from 1905 to 1921) show that general distribution was usually made before the middle of the calendar year following the year of the report.

Dr. Richard de Zeeuw, who was secretary of the Academy from 1912 to 1917, informs me that the preceding account is substantially correct, particularly with regard to the issuance of authors' separates, which were often, if not always, available several months before the bound volumes. This is important because priority of publication, according to the codes of nomenclature for both botany and zoology, can be established by the distribution to the public of these "preprints." Mere receipt of the preprints by the author does not constitute publication, but such publication *is* effected by his distribution of them. A preprint of pages 78–94 from the eighteenth volume, for example, an article by Oliver A. Farwell, was dated upon receipt by the author in December 1916; a copy of the same article was sent by Farwell to the Gray Herbarium of Harvard University and received on June 20, 1917. The bound volume was distributed in July or August 1917. Farwell's article must be regarded as having been published on or before June 20, 1917, at least a month before the issuance of the volume of which it was a part.

Publication of new names for plants or animals in this way, by distribution of preprints, is not to be recommended. It is usually difficult to establish the exact date of publication, and even more difficult to show that the author has sent out enough copies to constitute general distribution, as required at least by the Code of Zoological Nomenclature. In the example given above we infer that Farwell sent out several copies of his article in addition to the one received by the Gray Herbarium, and we should ordinarily accept June 20, 1917, as the date of publication. We cannot prove, however, that the article was properly and effectively published (i.e. distributed) before August 20, 1917, the date of distribution of the bound volume by the University of Michigan General Library.

Table I lists nine articles by Farwell in the volumes of the

Report, together with the dates of receipt of the preprints as noted by him (on his own copies at the Cranbrook Institute of Science) and the dates of receipt of the preprints at the Gray Herbarium.

TABLE I

DATES OF OLIVER A. FARWELL'S ARTICLES IN THE VOLUMES OF THE ANNUAL REPORT OF THE MICHIGAN ACADEMY

Volume	*Probable date of publication of bound volume*	*Article by Farwell (pages)*	*Preprint dated by Farwell*	*Date of receipt of preprint by Gray Herb., Harvard Univ.*
2	May (?) 1902	31–68	October 10, 1901	March 6, 1902
6	January 1905	200–214	October 10, 1904	October 31, 1904
15	February 1914	150–192	November 20, 1913	December 6, 1913
17	August 1917	167–182	October 20, 1916	(No copy)
18	August 1917	78–94	December 1916	June 20, 1917
19	June 1918	247–262	December 1917	March 15, 1918
20	May 20, 1919	155–198	December 1918	February 3, 1919
21	January 3, 1921	345–371	July 20, 1920	October 9, 1920
22	November 7, 1921	177–185	May 20, 1921	June 5, 1921

I have not been able to learn the dates of publication of any separate articles from the volumes of the *Report* except those of Farwell. It is to be presumed that preprints were sent by the printers to all authors at about the same time. Judging from the examples listed in Table I, it would appear that the preprints were generally available to the authors about six months ahead of the bound volumes, and publication (distribution) of individual articles by the author may have been effected at any time thereafter.

It is possible to fix the dates of publication of the bound volumes with somewhat more certainty, and the dates of individual articles should be regarded as the same as those of the volumes in which they appear unless definite evidence of earlier publication can be found. The records of the General Library of the University of Michigan show that it was its practice to send out all copies to its regular exchange list on the same day. In the absence of evidence of previous distribution, this date should be regarded as the date of publication.[2] Table II presents the information thus far

[2] Because of certain inconsistencies in the records of the General Library, and the absence of all records pertaining to the first five volumes, it has been necessary to consult the accession records of other libraries for additional information. I am

available, including that from the accession records of the University of Michigan General Library and of five other libraries which have nearly complete series. It should be noted that accession records cannot fix the actual date of issue of any volume, but they can establish dates *after which* the volumes in question cannot have been issued.

The dates of publication of the bound volumes are taken as those dates on which general distribution was made by the University of Michigan Library, unless there seems to be doubt of the exactness of such dates. There are many irregularities, i.e., single volumes known to have been received before the dates of general distribution. The ninth volume, for example, was sent out on February 26, 1908, and its receipt was noted by most of the libraries between February 29 and March 5. A copy was received by the Gray Herbarium, however, on February 20, and it is of course possible that other copies were sent out at this time. I have indicated the publication date of this volume, in Table II, merely as "February 1908," and a similar course has been followed for other volumes where the evidence is conflicting.

It may be noted especially that six of the first twelve volumes were received and catalogued at the University of Michigan Library before they were generally available elsewhere; also, certain volumes were received by nearby Michigan State College before general distribution.

Table III lists volumes 1 to 35 of the *Papers of the Michigan Academy* and the corresponding dates of the Academy meetings, together with the dates of publication shown on the title pages and the copyright dates from the Copyright Office at the Library of Congress. The copyright date is approximately that on which two copies of the volume in question were mailed to the Library of Congress; occasionally it appears that actual mailing was delayed beyond this date, for the Library of Congress records show that

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grateful for assistance in compiling these data and wish to acknowledge the kindness and interest of the librarians at the University of Michigan and also at the Academy of Natural Sciences of Philadelphia, the Chicago Natural History Museum, the New York Botanical Garden, the United States Department of Agriculture, the Library of Congress, the University of Minnesota, and Michigan State College. I am especially grateful to Miss Marjorie W. Stone, of the Gray Herbarium, who has been very patient and helpful on many occasions.

TABLE II

DATES OF THE FIRST TWENTY-TWO VOLUMES OF THE ANNUAL REPORT OF THE MICHIGAN ACADEMY

Volume	Probable date of publication of bound volume	Distributed by Univ. Mich. Library	Date on title page	Date of letter of transmittal	Catalogued at Univ. Mich. Library	Received by Acad. Nat. Sci. Phila.	Received by N. Y. Bot. Garden	Received by Univ. Minn.	Received by Chicago Nat. Hist. Mus.	Received by Gray Herb., Harvard Univ.
1	October 1900	No record	1900	1 D 1899	6 N 1900	29 N 1900	3 N 1900	....	....	....
2	May (?) 1902	No record	1901	30 N 1900	....	6 Je 1902	....	....	....	....
3	May 1902	No record	1902	26 Mr 1902	....	17 My 1902	....	3 Je 1902	8 My 1902	....
4	May 1904	No record	1904	18 D 1903	N 1904	21 My 1904	25 My 1904	....	....	23 My 1904
5	June 1905	No record	1904	1 D 1904	Mr 1905	5 Jl 1905	3 Jl 1905	8 Jl 1905	27 Je 1905	3 Jl 1905
6	January 1905*	12 My 1905	1904	14 My 1904	22 N 1904	5 Jl 1905	1 Jl 1905	21 Ja 1905	....	3 Jl 1905
7	April 1906	13 Ap 1906	1905	5 My 1905	....	23 Ap 1906	20 Ap 1906	18 Ap 1906	24 Ap 1906	23 Ap 1906
8	November 1906*	9 Ja 1907	None	1 My 1906	3 Ja 1907	22 Ja 1907	....	23 Ja 1907	11 F 1907	24 Ja 1907
9	February 1908*	26 F 1908	None	31 Au 1907	....	29 F 1908	2 Mr 1908	2 Mr 1908	5 Mr 1908	20 F 1908
10	November 1908	4 N 1908	1908	28 My 1908	2 N 1908	16 N 1908	17 N 1908	27 N 1908	21 N 1908	16 N 1908
11	February 1910*	1 Mr 1910	1909	16 Je 1909	24 Ja 1910	11 Mr 1910	7 Mr 1910	3 Mr 1910	4 Mr 1910	25 F 1910
12	October 1910*	20 N 1910	1910	My 1910	7 O 1910	21 N 1910	21 N 1910	4 N 1910	9 D 1910	7 N 1910
13	December 1911*	"25" D 1911	1911	My 1911	....	29 Ja 1912	20 F 1912	1 F 1912	2 F 1912	25 Ja 1912
14	October 1913*	20 O 1913	1912	1912	....	17 O 1913	18 O 1913	29 O 1913	8 D 1913	13 N 1913
15	February 1914*	14 F 1914	1913	My 1913	13 Jl 1914	23 My 1914	23 My 1914	27 My 1914	20 My 1914	14 My 1914
16	March 1916	23 Mr 1916	1914	N 1914	....	29 Mr 1916	31 Mr 1916	31 Mr 1916	17 Ap 1916	29 Mr 1916
17	August 1917*	20 Au 1917	1916	N 1915	....	16 Au 1917	20 Au 1917	22 Au 1917	8 S 1917	25 Au 1917

TABLE II (*Continued*)

18	August 1917*	20 Au 1917	1916	N 1916	....	16 Au 1917	20 Au 1917	22 Au 1917	8 S 1917	25 Au 1917
19	June 1918*	25 Jl 1918	1917	Je 1917	....	28 Je 1918	30 Jl 1918	29 Jl 1918	10 Jl 1918	2 Jl 1918
20	May 1919*	20 My 1919	1918	Je 1918	5 Je 1919	22 My 1919	23 My 1919	5 Je 1919	29 My 1919	26 My 1919
21	January 1921*	3 Ja 1921	1920	Je 1919	....	13 Ja 1921	13 Ja 1921	24 F 1921	14 Ja 1921	24 Ja 1921
22	November 1921*	7 N 1921	1921	N 1920	19 N 1921	14 D 1921	....	22 D 1921	16 D 1921	19 D 1921

* See comment below, under volume number:

Volume 6.—So dated because the University of Minnesota received a copy on January 21, 1905; general distribution to libraries seems to have been in June 1905.

Volume 8.—Copy received by Michigan State College on November 24, 1906; general distribution evidently on January 9, 1907.

Volume 9.—Copy received by Gray Herbarium on February 20, six days before the general distribution.

Volume 11.—Copy received by Gray Herbarium on February 25, four days before the general distribution.

Volume 12.—At least three libraries received copies before November 10, and one by November 4.

Volume 13.—This date is tentative, for January 25, 1912, is the earliest date by which any library is known to have received a copy, and it seems unlikely that any were actually distributed from the University of Michigan Library on Christmas Day 1911, as indicated in the records.

Volume 14.—Two libraries received copies before the general distribution on October 20.

Volume 15.—So dated because of record of distribution on "2-14-1914" at the University of Michigan; no library is known to have received a copy before May 14, 1914.

Volumes 17, 18.—These two volumes were sent out together; a special rubber stamp bearing the date August 20, 1917, was prepared to mark the distribution records at the University of Michigan. The Academy of Natural Sciences of Philadelphia, however, received its copies on August 16. The records of the library of the United States Department of Agriculture show that volume 18 was received July 30, 1917, but I regard this as doubtful; the companion volume, 17, was not stamped with the date of receipt by the Department of Agriculture and may have been received at a different time. This in turn may cast doubt upon the date recorded for volume 18.

Volume 19.—Several libraries received copies some time before July 25; in addition to those noted in the table, the records at Michigan State College indicate that a copy was received before July 3.

Volume 20.—Date of publication is given on reverse of title page as November 22, 1919 (by error for 1918).

Volume 21.—Date of publication is given on reverse of title page as July 1920. A copy at Michigan State College (accession no. 40880) was apparently received in October 1920.

Volume 22.—Date of publication is given on reverse of title page as August 1921.

some volumes were received as much as two months after the copyright date. Except for discrepancies of this kind, there is little uncertainty about the dates of publication of the *Papers*, as these dates are indicated in each volume on the title page and in one case only (volume 2) is the copyright date later than the year shown on

TABLE III

DATES OF THE PAPERS OF THE MICHIGAN ACADEMY, VOLUMES 1–35

Volume and year of meeting	Date at foot of title page	Copyright date	Volume and year of meeting	Date at foot of title page	Copyright date
1 (1921)	1923*	April 26, 1923	18 (1932)	1933	March 29, 1933
2 (1922)	1923	January 18, 1924	19 (1933)	1934	March 14, 1934
3 (1923)	1924	March 15, 1924	20 (1934)	1935	June 1, 1935
4(1) (1924)	1925	March 14, 1925	21 (1935)	1936	June 30, 1936
4(2) (1924)	1925	March 30, 1925	22 (1936)	1937	June 23, 1937
5 (1925)	1926	February 8, 1926	23 (1937)	1938*	May 4, 1938
6 (1926)	1927	March 21, 1927	24 (1938)	1939‡	May 25, 1939
7 (1926)	1927	April 7, 1927	25 (1939)	1940‡	April 10, 1940
8 (1927)	1928	February 29, 1928	26 (1940)	1941†‡	March 15, 1941
9 (1928)	1929	March 14, 1929	27 (1941)	1942‡	March 30, 1942
10 (1928)	1929	April 13, 1929	28 (1942)	1943‡	February 19, 1943
11 (1929)	1930	February 28, 1930	29 (1943)	1944†‡	May 30, 1944
12 (1929)	1930	March 15, 1930	30 (1944)	1945†‡	September 25, 1945
13 (1930)	1931	March 9, 1931	31 (1945)	1947‡	October 31, 1947
14 (1930)	1931	March 18, 1931	32 (1946)	1948‡	August 27, 1948
15 (1931)	1932	March 1, 1932	33 (1947)	1949‡	March 28, 1949
16 (1931)	1932	April 20, 1932	34 (1948)	1950‡	April 14, 1950
17 (1932)	1933	March 16, 1933	35 (1949)	1951‡	March 9, 1951

* Oliver A. Farwell twice noted receipt of his reprints in advance of date of issue of the bound volume, the reprints from volume 1 having been received in February 1923, and those from volume 23 in April 1938.

† Volumes 26, 29, and 30 were not received by the Library of Congress until more than a month after the stated copyright dates (on April 21, 1941, August 7, 1944, and December 12, 1945, respectively). This suggests that actual publication (i.e., distribution to the public) of these volumes was delayed until approximately these dates.

‡ Volumes 24 to 35 inclusive bear on the title page not only the date of issue, e.g., "1939," but, in conjunction with the volume number, the year of the meeting, e.g., "Volume XXIV (1938)."

the title page. In addition to this, the actual dates of issue of each of the first three volumes are given in volume 4, and the dates of volumes 4 to 8 inclusive are noted, each in turn, in volumes 5 to 9.

Nonetheless, confusion has arisen with regard to the dates of publication of the *Papers*, because the volumes are serially numbered to correspond with the annual meetings of the Academy, and the dates of these meetings do not precede the dates of publication

by any consistent interval. Volume 1, for example, was published in 1923, but it contains the papers read at the meeting of 1921 and it bears the date 1921 on the spine. Volume 3, on the other hand, was published in 1924, but contains the papers of the 1923 meeting. Many of the volumes have the date of the Academy meeting on the spine and certain of them, some copies of which were bound in paper, have that date on the front of the paper binding,[3] where it has sometimes been taken for the date of issue. Volumes 24 to 35 inclusive bear on the title page not only the date of issue, e.g. "1939," but, in conjunction with the volume number, the date of the related Academy meeting, thus: "Volume XXIV (1938)." Furthermore, meeting date has been associated with volume number within the *Papers* themselves in the citation of previous volumes, thus: "*Pap. Mich. Acad. Sci., Arts, and Letters*, 24 (1938): 1–56. 1939." Such a system would appear to be not only cumbersome, but likely to breed confusion among those using the volumes. It seems unnecessary to refer to the date of meeting of a society when citing a paper presented at that meeting but not published until much later; bibliographic necessity demands no more than volume number, page, and date of issue. Perhaps even more confusion has arisen because in advertisements in the *Papers* themselves, and elsewhere in University advertising, the several volumes are noted by volume number and date of meeting, rather than by date of issue.

Beginning with volume 36, it is planned to have each volume of the *Papers* include a mention of the actual date of issue of the preceding volume; this practice, as has been noted above, was followed for some years, but was discontinued with volume 10.

University of Michigan

[3] A part of the edition of each of the first twenty-three volumes of the *Papers* was issued in inexpensive paper covers; the remainder of the edition was permanently bound in boards. Both were distributed from the University of Michigan Library. Beginning with volume 24 and continuing to the present, the entire edition of the complete volume has been bound in boards.

*STILBUM TOMENTOSUM**

EDWIN B. MAINS

STILBUM TOMENTOSUM Schrad. ex Fr. has been placed in Tilachlidium by Lindau (1908), and the writer's attention (1951) was first turned to it in a study of entomogenous species of Tilachlidium. It is a fairly widely distributed although not a common parasite of Myxomycetes. Apparently it has not previously been recorded from Michigan. As a result of a request to C. J. Alexopoulos and E. S. Beneke to watch for the species in their studies of the Myxomycetes of Michigan, a collection of a Stilbum on *Hemitrichia serpula* (Scop.) Rost. was received from them in 1950. This specimen, while agreeing in spore size with a collection in the Herbarium of the University of Michigan, has spores considerably larger than those of a specimen of *Tilachlidium tomentosum* in the Farlow Herbarium.

So far as the writer has been able to determine, four species of Stilbum, namely, *S. tomentosum* Schrad. ex Fr., *S. orbiculare* Berk. & Br., *S. echinatum* Ell. & Ev., and *S. capillare* Ell. & Ev., have been described as parasites of Myxomycetes. Much information has been published concerning *S. tomentosum*, and this has been reviewed by Petch (1945). The descriptions of this species give considerable differences in spore size, and the surface of the stipe has been reported as tomentose, glandular, and smooth.

Stilbum orbiculare was described and illustrated by Berkeley and Broome (1878) on *Lindbladia effusa* from Great Britain. They state that the spores are oblong, minute, 0.0002 in. (5 μ), and that the stipes are tomentose, sometimes with a lacerated veil at the apex.

Stilbum echinatum was described on *Arcyria cinerea* from New York by Ellis and Everhart (1885). They state that the spores are globose, minute, 0.5 μ, and that *S. tomentosum* differs in being a much coarser plant with oblong spores, 4–5 $\times$ 1.5 μ.

* Paper from the Herbarium and the Department of Botany of the University of Michigan.

Stilbum capillare was described on *Trichia varia* from New York by Ellis and Everhart (1888). They report that the stipes are smooth and that the spores are oblong-elliptical, 3–4 × 0.75 μ. They do not make comparisons with *S. tomentosum* or *S. echinatum*, but say that *S. capillare* resembles *S. aciculosum*, a species previously described by them on decaying leaves of *Orontium aquaticum* which has a glandular-tomentose stipe and flesh-colored heads in contrast to the smooth stipe, smaller, paler heads, and larger conidia of *S. capillare*.

To judge from the literature, the five species do not greatly differ. In order to obtain more information concerning the relationship of the species, collections were borrowed from the Herbarium of the New York Botanical Garden, through the kindness of Donald P. Rogers. They included specimens from the Ellis collection, which contains types of *Stilbum echinatum*, *S. capillare*, and *S. aciculosum*.

The specimen of *Stilbum echinatum* labeled "type" bears the data "on *Arcyria*, Adirondack Mts., Dr. Rex." No date is given. The following information has been derived from a study of this specimen.

Sporangia of the host covered with a thin white mycelium; synnemata (Pl. I, Fig. 1) white, scattered, 400–600 μ long, capitate, the heads subgloboid, 60–100 × 75–110 μ, covered with glutinous masses of spores and mucus, the stipes 20–30 μ thick bearing many globoid to ellipsoid inflated cells on the surface (Pl. I, Fig. 2), with surfaces of hyphae and inflated cells minutely granulose; hyphae from the stipes repeatedly branching above in the head, the branches terminating in phialides, which form a peripheral layer of the heads; phialides subulate, 6–10 × 1.5 μ, acuminate above; conidia hyaline, subgloboid to broadly ellipsoid, minute, 1.1–1.7 × 1.0–1.2 μ (Pl. I, Fig. 3), agglutinating into a yellow layer covering the head.

In the description of the species Ellis and Everhart (1885) give the dates August 1884 and 1885, thus citing at least two specimens. Among the collections in the Herbarium of the New York Botanical Garden there is a specimen under "*S. tomentosum*" collected by George A. Rex, August 1885 in the Adirondack Mts. This has oblong conidia, 4–6 × 2–2.5 μ. Whether it is the other specimen cited by Ellis and Everhart is uncertain, since they describe the spores of the species as minute, 0.5 μ. The specimen labeled "type"

was probably collected in 1884. There are two other specimens in the Ellis collection which are determined as *Stilbum echinatum*, one on *Trichia varia* from Ottawa, Canada, and the other on *T. scaber* from London, Canada. They differ from the type in having conidia which are ellipsoid to fusoid, 2–4 × 1.5 μ.

There are only two specimens in the Ellis collection determined as *Stilbum capillare*. They are both numbered 243 and are labeled "type." One bears the data "parasitic on *Trichia varia*, Jamesville, N. Y., Oct. 87, O. F. Cook," and the other, "Jamesville, N. Y. Oct. 1887. O. F. C." The following information has been derived from a study of these specimens.

Sporangia of the host covered with a thin white mycelium; synnemata (Pl. I, Fig. 6) white, scattered, 370–600 μ long, capitate, the heads obovoid, 75–100 × 50–80 μ, the stipes 18–34 μ thick, bearing many globoid to obovoid inflated cells on the surface, with surfaces of hyphae and inflated cells minutely granulose; phialides in a peripheral layer of the head, subulate, 12–22 × 2 μ, acuminate above; conidia oblong to subfusoid, 3–8 × 1.5–2.5 μ, agglutinating and forming a thick layer on the head.

Stilbum capillare does not differ greatly from *S. echinatum* except in the shape and size of the conidia.

There are two specimens of *Stilbum aciculosum* in the Ellis collection, both on decaying leaves of Orontium from Newfield, New Jersey. One has the date "Oct. 18, 1879," and the other, "July 22, 85." Since the date given in the publication of the species is July 22, 1885, the latter specimen is the type. The following description is derived from the type.

Synnemata few, very slender, 400–1180 μ long, capitate, the heads ellipsoid to globoid, 75 × 50–75 μ, the stipe 20–24 μ thick, smooth except for a minutely granulose condition; phialides subulate, 14–20 × 2–2.5 μ; conidia oblong to subfusoid, 4–6 × 2 μ, agglutinating to form a layer on the head.

The collection dated "Oct. 18, 1879," has smooth or minutely granulose stipes and conidia which are subfusoid, 4–7 × 1.5–2 μ. *Stilbum aciculosum* therefore differs from *S. capillare* principally in the lack of inflated cells on the stipe.

In a study of collections identified as *Stilbum tomentosum* or *Tilachlidium tomentosum* the variations which have been noted by others were found. One collection has spores which are globoid to

broadly ellipsoid and very small, 1–1.5 × 1 μ. Seven collections have spores which are oblong, narrowly ellipsoid or subfusoid, (2.5) 3–6 (7) × 1.5–2.5 μ. The stipes of most collections bear inflated cells. In a few collections the stipes are smooth except for a very minutely granular condition of the hyphae.

Fries (1832) recognized *Stilbum parasiticum* Pers. as a glabrous variation of *S. tomentosum* with the statement "videtur adultior status." From descriptions given in the literature it appears that the glabrous stipes are not correlated with spore size. Petch (1945) has reported that the synnemata of some specimens of *S. tomentosum* bear conidiophores of a Cephalosporium. This may account for some descriptions of the stipes as tomentose.

Concerning the differences in spore size, Annie Lorrain Smith (1902) states that "the differences between the spores of the two kinds of Stilbum amount almost to a specific distinction but the plants are so much alike that it seems better to distinguish the second as a variety." She therefore recognized the large-spored form as a variety, *ovalisporum*. Ferraris (1909) independently reached similar conclusions, using the name *Stilbella tomentosa* var. *macrospora*. Whether the species was based on the small-spored form is debatable. Schrader (1799) does not describe or illustrate the spores. Ditmar (1817) describes the spores of *Stilbum parasitum* as very small, and their magnification in his illustration is not enough to establish the type of spore. Fries gives no information concerning spore size but cites Greville (1827), who notes that the spores are very minute and globoid. It seems desirable to follow the treatments of Smith, Ferraris, and Petch and to recognize two varieties of *S. tomentosum*, the large-spored as var. *ovalisporum* and the small-spored as var. *tomentosum*.

Stilbum echinatum does not differ from the variety *tomentosum*, and *S. capillare* is var. *ovalisporum*. *S. aciculosum* is similar to collections of *S. tomentosum ovalisporum* which have smooth stipes. Petch was able to grow *S. tomentosum ovalisporum* on oatmeal agar with the production of typical synnemata and conidia. It may therefore also occur in a saprophytic condition in nature. It is also possible that *S. aciculosum* may have developed on a plasmodium, which probably would not be evident in a herbarium specimen.

Stilbum orbiculare has not been available for study. From the description of the species it probably is *S. tomentosum ovalisporum*. Berkeley and Broome state that sometimes a lacerated veil occurs

at the apex of the stipe, and they illustrate it for one synnema. If the fungus is a Stilbum, some other interpretation is necessary. In some specimens of *S. tomentosum* the lower phialides of the head become agglutinated together and separated somewhat from the others. This might occasionally result in a development such as is illustrated for *S. orbiculare*.

The transfer of *Stilbum tomentosum* to Tilachlidium is not justified, as has been shown by Ferraris and Petch. According to Petch, Lindau based his transfer on Grimm's description (1899) of lateral conidiophores, which Petch reports are the conidiophores of a Cephalosporium growing on the synnemata of *S. tomentosum*. Regardless of this, the terminal head of phialides of *S. tomentosum* excludes it from the genus Tilachlidium.

The results of this study are here summarized. The specimens cited are designated FH (Farlow Herbarium of Harvard University), NY (Herbarium of the New York Botanical Garden), and M (Herbarium of the University of Michigan).

Stilbum tomentosum Schrad. ex Fr.

Systema Mycologicum, 3: 301. 1829

Stilbum parasiticum Pers. ex Ditmar, Sturm's Deutsch. Flora, Bd. I, Abt. 3: 93. 1817.
Stilbella tomentosa (Schrad. ex Fr.) Bres., Ann. Mycol., 1: 129. 1903.
Dendrostilbella tomentosa (Schrad. ex Fr.) v. Höhn., Oesterr. Bot. Zeitschr., 66: 110. 1916.

Synnemata white, arising from a thin white mycelium, 0.3–2.0 mm. long, capitate, the heads obovoid, ellipsoid or subgloboid, 60–250 × 50–250 μ, the stipes 20–145 μ thick, composed of parallel longitudinal hyphae, minutely granulose, usually bearing few to many globoid, ellipsoid, or oblong inflated cells, 3–4 × 2–3 μ, or occasionally without inflated cells; phialides forming a peripheral layer of the head, subulate, 6–22 × 1.5–2.5 μ, acuminate above; conidia hyaline, with a mucus, agglutinating in a thick layer covering the head.

S. tomentosum var. *tomentosum*

(Pl. I, Figs. 1–5)

Stilbum echinatum Ell. & Ev., Journ. Mycol., 1: 153. 1885.

Conidia subgloboid to broadly ellipsoid, 1–1.7 × 1–1.2 μ.
On *Arcyria sp.*, Canton, Mass., Sept. 1933, D. H. Linder, Pl. I,

Figs. 4–5 (FH); on *Arcyria sp.*, Adirondack Mts., N. Y., Geo. A. Rex, type of *Stilbum echinatum* (NY); on *Hemiarcyria clavata*, Long Island, N. Y., Aug. 1889, 330 (NY).

S. tomentosum var. *ovalisporum* A. L. Smith

Trans. Brit. Mycol. Soc., 2: 26. 1902

(Pl. I, Figs. 6–8)

Stilbum orbiculare Berk. & Br., Ann. Mag. Nat. Hist., 1878: 28.
Stilbum aciculosum Ell. & Ev., Journ. Mycol., 1: 153. 1885.
Stilbum capillare Ell. & Ev., Journ. Mycol., 4: 46. 1888.
Stilbella tomentosa var. *macrospora* Ferraris, Ann. Mycol., 7: 277. 1909.

Conidia oblong, narrowly ellipsoid or subfusoid, (2.5) 3–6 (8) × 1.5–2.5 μ.

On *Hemitrichia serpula*, White Pine, Mich., Aug. 19, 1950, C. J. Alexopoulos and E. S. Beneke, Pl. I, Fig. 8 (M); on *Trichia varia*, Jamesville, N. Y., Oct. 1887, O. F. Cook, type of *Stilbum capillare*, Pl. I, Figs. 6–7 (NY); on myxomycete, Adirondack Mts., N. Y., Aug. 1885, George A. Rex (NY); on myxomycete, Chocorua, New Hampshire, July 19, 1912, W. G. Farlow, Rel. Farl. 201 (M); on myxomycete, Ohio, Morgan, 524 (NY); on *T. scaber*, London, Canada, Nov. 1890, J. Dearness, 576 (NY); on *T. varia*, Ottawa, Canada, May 9, 1891 (NY); inside of decaying logs, Mt. Shasta, Wash., June 26, 1939, Wm. Bridge Cooke, 13277 (FH); on decaying leaves of Orontium, Newfield, N. J., July 22, 1885, type of *S. aciculosum* (NY); on decaying leaves of Orontium, Newfield, N. J., Oct. 18, 1879 (NY); on *Trichia sp.*, Bohemia, Kav. Hil. Crypt. Cechosl. exsicc. 260 (NY); Vize, Micro-Fungi Brit. 354 (NY).

Berkeley and Broome (1875) have reported that *Stilbum tomentosum* is the conidial stage of *Hypomyces stilbiger* Berk. & Br. Whether they actually found the perithecial and conidial stages associated is questionable. Petch (1945) states that the conidial stage, Thwaite's no. 83, Peradeniya, Ceylon, is dated November 1867 and that "*Hypomyces stilbiger* which is also Thwaite's no. 83 was collected December 1868." Penzig and Saccardo (1904) described *Ophionectria* (*Ophiostilbe*) *trichiae* on *Trichia verrucosa* from Java. They illustrate perithecia associated with synnemata, which they consider those of *S. tomentosum*. Conidia were not seen. Petch (1912) has established a genus Byssostilbe, with *Hypomyces stilbiger*

as the type. He (1945) regards *Ophionectria trichiae* as the same as *Byssostilbe stilbiger* and reports that he was unable to find any record of the perithecial stage outside Ceylon and Java.

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EXPLANATION OF PLATE I

FIGS. 1–5. *Stilbum tomentosum* var. *tomentosum*

FIG. 1. Synnemata. × 20

FIG. 2. Stipe showing inflated cells. × 1000

FIG. 3. Conidia. × 1200

FIG. 4. Synnemata on sporangia of Arcyria. × 10

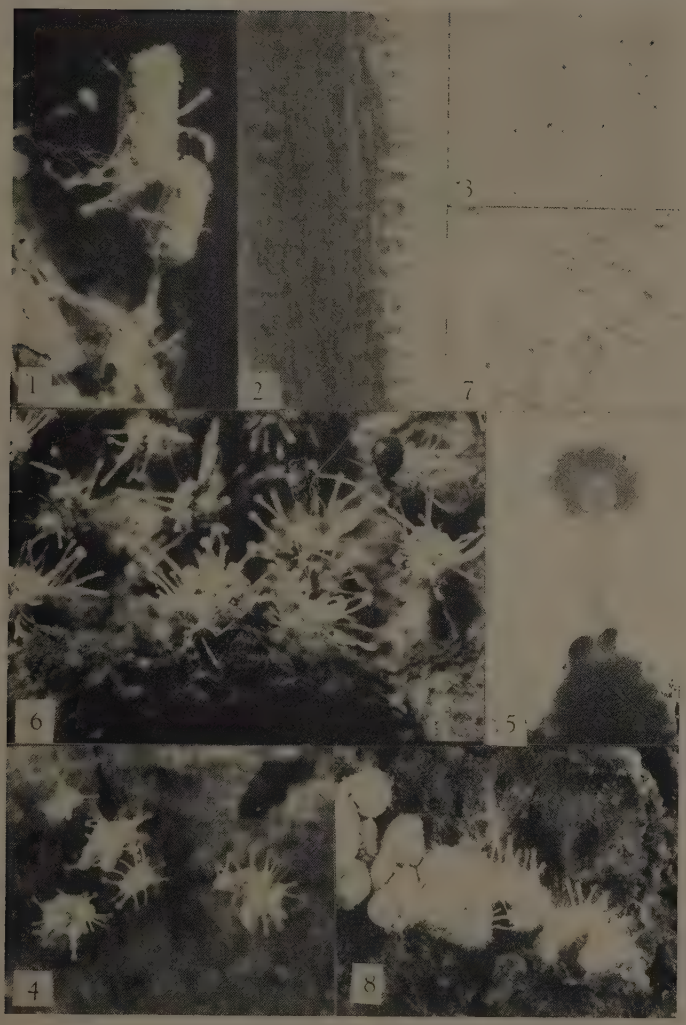
FIG. 5. Synnema showing agglutinated conidia covering the head. × 65

FIGS. 6–8. *Stilbum tomentosum* var. *ovalisporum*

FIG. 6. Synnemata. × 20

FIG. 7. Conidia. × 1200

FIG. 8. Synnemata on sporangia of *Hemitrichia serpula*. × 10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NEW AND RARE AGARICS FROM THE DOUGLAS LAKE REGION AND TAHQUAMENON FALLS STATE PARK, MICHIGAN, AND AN ACCOUNT OF THE NORTH AMERICAN SPECIES OF XEROMPHALINA*

ALEXANDER H. SMITH

SINCE the season of 1946 an intensive study of the fleshy fungi of northern Michigan has been in progress. With the University of Michigan Biological Station as headquarters, the tip of the Southern Peninsula, here referred to as the Douglas Lake Region, and Tahquamenon Falls State Park, in the Upper Peninsula, were studied intensively. During this time a large number of rare and interesting species were found, some of which have been reported (Smith, 1952). The present contribution consists of two parts. Part I is a general list which contains information on taxa on which more descriptive data were needed to characterize them properly, and also taxa regarded as previously undescribed. Part II consists of a revision of the genus Xeromphalina in North America. This revision was stimulated by the discovery of *X. picta* at Tahquamenon Falls by Miss Sheila Hoare, of the Canadian Department of Agriculture, who spent the summer of 1951 working at the Biological Station. All but two of the eight species recognized in the genus are known from Michigan.

Additional contributions are to be expected as more of the unidentified collections are studied. The ultimate aim is, of course, to revise the Agaricaceae of Michigan and bring it up to date.

The specimens cited are deposited in the University of Michigan Herbarium at Ann Arbor, Michigan. The color terms within quotation marks are those of R. Ridgway.[1]

* Papers from the University of Michigan Herbarium and the Department of Botany, University of Michigan, Ann Arbor, Michigan. The cost of excess pages and illustrations has been paid by the University of Michigan Herbarium.

[1] *Color Terms and Color Nomenclature* (Washington, D.C., 1912).

PART I

General List of Species

1. *Armillaria robusta* (Fr.) Kummer

Pileus 4–10 cm. broad, convex with an inrolled margin, expanding to plane or broadly umbonate, surface dry and appressed-fibrillose (matted down), fibrils soon breaking up into scales or separating to form streaks, "Sayal brown" to "snuff brown" at first, gradually becoming darker, in age deep reddish brown, margin appendiculate with cottony veil remnants; flesh white, thick, hard, tending to stain orange brown where bruised, taste rancid-farinaceous, odor farinaceous and often strong; lamellae close, broad, adnexed, "tilleul buff" with a tendency to become vinaceous brown where bruised, edges eroded; stipe 6–9 cm. long, 1–2 cm. thick, usually narrowed below, solid, hard, white within but soon orange brown around wormholes, with a superior annulus which terminates a sheath, the sheath becoming broken into zones or patches of orange-brown fibrils or tissue, pallid and silky to squamulose above, base often "orange cinnamon."

Spores 5–6 × 4.5 μ, white in deposit, hyaline in KOH, pallid yellow in Melzer's solution, smooth, broadly ellipsoid; basidia four-spored, 28–34 × 6–7 μ; no pleurocystidia or cheilocystidia seen; gill trama parallel or nearly so, central stratum with cells broader than in lateral strata; pileus trama homogeneous beneath a nongelatinous cuticle of narrow interwoven orange-brown hyphae; no clamp connections seen.

Habit, habitat, and distribution.—Gregarious under pine, spruce, fir, and aspen at the edge of a bog, Tahquamenon Falls State Park, Sept. 19, 1949, Smith 33969, and Sept. 13, 1951, Smith 38775.

Observations.—The mature fruiting bodies are deep red brown, and the surface of the pileus is dry at all stages. I have used the concept of Kauffman (1923), which is clearly in line with the Friesian descriptions. *Armillaria Zelleri*, a viscid species, has been reported under the name *A. robusta*.

2. **Cantharellus cinereus** Fries f. **multiplex**, f. nov.

(Pl. I)

Dense caespitosus; sporae 8–11 × 5–6 μ; stipes ramosus. Specimen typicum, in Herb. Univ. Mich. conservatum, legit prope Burt Lake, Mich., Aug. 8, 1951, A. H. Smith n. 37531.

Fructification compound, 6–10 cm. broad and 8–12 cm. high; pileus 1–4 cm. broad, centrally to laterally stipitate (often merely eccentric), more or less funnel-shaped and deeply perforated, glabrous or nearly so and faintly zoned, becoming uneven to somewhat squamulose, the margin pallid and often crenate, central part smoky fuscous to "mummy brown"; flesh thin, concolorous with surface, taste slightly disagreeable, odor faint and not distinctive; lamellae decurrent, veinlike but very distinct and well formed, close to subdistant, deep cinereous becoming paler bluish gray; stipe compound and much branched, hence variable, surface smooth, hollow and darker within.

Spore deposit white, spores 8–11 × 5–6 μ, smooth, hyaline in KOH, hyaline to yellowish in Melzer's solution; basidia 4-, 6-, or 8-spored, 40–69 × 8–9 μ; no pleurocystidia or cheilocystidia seen; gill trama loosely interwoven, the hyphae not or only slightly differentiated; pileus trama homogeneous, pale brown in KOH; clamp connections not found.

Habit, habitat, and distribution.—On the ground in mixed woods, along with each group of clusters or single cluster there usually occurred a few carpophores gregariously, Colonial Point, Burt Lake, July 6, 1951, Smith 36695, Aug. 8, Smith 37531.

Observations.—The massive fructifications remind one of those of *Cantharellus multiplex*, but the latter is readily distinguished by its small rough spores and the reaction of the flesh (greenish) in KOH. In all respects the Michigan material fits well the concept of *C. cinereus* with the exception of the habit, and that difference could be the result of vigorous mycelium growing during an exceptionally favorable season. Since f. *cinereus* nearly always occurred in the vicinity of f. *multiplex*, the impression one gets is definitely that the latter is merely a growth form, but it should be put on record because it could easily be mistaken for *C. multiplex* in the field. For a detailed study of *C. multiplex* see Smith and Morse (1947).

3. *Cantharellus lutescens* Fries

(Pl. II)

Pileus (1) 2–4 (8) cm. broad, broadly convex to nearly plane at first, margin curved in, sometimes disc sharply depressed at first, expanding to shallowly funnel-shaped and the margin becoming wavy and irregular, disc often perforated (especially in age), in large caps the perforation broad and extending into the hollow of the stipe,

surface moist and hygrophanous, when young minutely squamulose to fibrillose-scurfy or practically glabrous, in age more often uneven than scaly, color bright orange yellow ("capucine yellow" and fading to "pale yellow orange"), in age faded caps often near "cinnamon buff" and, when dried, grayish; flesh soft and fragile, concolorous with pileus, odor slight but fragrant, taste somewhat unpleasant; lamellae distinct and well formed, decurrent, narrow, many of them forked, subdistant, becoming intervenose, "ochraceous salmon" varying to "vinaceous cinnamon" (salmon-yellow becoming dingy), edges obtuse; stipe 3–5 cm. long, 4–10 mm. thick, central or eccentric, "capucine yellow" or a darker orange, moist, glabrous, hollow, gradually fading to dingy yellowish, not discoloring when handled.

Spores "ochraceous salmon" in deposit, 9–13 × 6.5–8 μ, broadly ellipsoid, smooth, hyaline in KOH, yellowish in Melzer's solution; basidia 4–6-spored, 70–90 × 8–10 μ; no pleurocystidia or cheilocystidia seen; gill trama with a central loosely interwoven portion and a more compactly interwoven subhymenium; pileus trama homogeneous, pallid in Melzer's solution; clamp connections abundant.

Habit, habitat, and distribution.—Cespitose-gregarious on barren sandy soil in open oak and pine woods, during wet weather in the summer and fall, east shore of Burt Lake, July 18, 1951, Smith 36985, July 27, Smith 37131; Tahquamenon Falls State Park, Aug. 13, 1951, Smith 37792.

Observations.—This is the characteristic Cantharellus of the pine barrens and is very distinct from *C. cinereus*, *C. tubaeformis*, *C. infundibuliformis*, and *Craterellus lutescens*. *Cantharellus tubaeformis* lacks the conspicuous orange-yellow color, grows in bogs (frequently under larch), and has a white spore deposit. *Craterellus lutescens* has spores colored like those of *Cantharellus infundibuliformis*, but the latter has young caps which are dingy yellow brown ("Brussel's brown") and which become dingy yellow only in age. It grows mostly on very decayed conifer logs. *Craterellus lutescens* lacks well-formed gills, the under surface of the cap being merely somewhat wrinkled at the most. I have observed it abundantly in Rees's bog. *Cantharellus cinereus* is readily distinguished by its color and lack of clamp connections. I have now seen all of these fruiting in quantity, and am convinced that they represent easily recognizable species.

4. *Clitocybe alba* Batsch ex Singer

Pileus (4) 5–12 cm. broad, convex with an incurved margin, expanding to broadly convex or nearly plane, surface white but with some watery, very pale buff spots, subviscid when wet (soft, as in Melanoleuca), with a satiny luster, particularly near the slightly pruinose-pubescent margin; flesh thick, white, soft, odor disagreeable, as in *Clitocybe nebularis*, taste rancid to merely disagreeable; lamellae close to crowded, narrow (4–7 mm.), 3–5 tiers of lamellulae, adnate but becoming short-decurrent, white when young, creamy in age, edges becoming somewhat eroded; stipe 4–7 cm. long, 15–25 mm. thick, clavate, bulbous, base soft and spongy and with copious mycelium surrounding it, dingy-pallid within the upper part, surface whitish and unpolished ("tilleul buff").

Spores pale yellow in deposits, 7–8 × 4.5–5 μ, narrowly ellipsoid, or in side view with a curved apiculus, pallid yellow in Melzer's solution, smooth, thin-walled; basidia four-spored, 24–28 × 6–7 μ; no pleurocystidia or cheilocystidia seen; gill trama somewhat interwoven; pileus trama homogeneous beneath an interwoven pellicle of slightly gelatinous (in KOH) hyaline hyphae of about the same size as those of flesh beneath; clamp connections present.

Habit, habitat, and distribution.—Gregarious under oak in open oak-hickory woods, George Reserve, Pinckney, Oct. 3, 1945, Smith 20956; Mackinaw City hardwoods, Sept. 16, 1950, Thiers and Smith 35892; same place, Aug. 31, 1951, Smith 38373; Tahquamenon Falls State Park, Sept. 9, 1951, Smith 38644.

Observations.—This fungus has much the stature of *Clitocybe nebularis* and is certainly closely related, but can hardly be classed as a white form. I have observed *C. nebularis* in quantity on the West Coast and never noticed that it had a pale-yellow spore deposit. This point needs further checking, however. From my observations the cap surface in *C. alba* is more like that of the genus Melanoleuca, whereas that of *C. nebularis* appears appressed-fibrillose.

5. *Clitocybe gilvaoides* Kauffman

Pileus 4–9 cm. broad, when young plane to slightly umbonate and margin incurved, expanding to shallowly depressed, surface glabrous and moist to lubricous, soon showing a pattern of subcuticular areolations or concentric zones, in age disc with obscure

spotlike scales or minute squamules, color at first dingy orange brown, darker and dull leather-red to bay brown in age, buttons dingy ochraceous-orange buff; flesh concolorous with surface and changing like it, odor and taste not distinctive or slightly farinaceous; lamellae close, narrow, decurrent, dingy pinkish cinnamon at first but gradually darkening to a more vinaceous cinnamon (concolorous with cap margin); stipe short, 1–4 cm. long, 6–12 mm. thick, usually enlarged downward, becoming hollow, surface faintly fibrillose to unpolished, in age nearly hoary, nearly concolorous with pileus (pale when young, dark in age), with copious mycelium intergrown with needles at base.

Spores 5–5.5 × 3.5 μ, oval, smooth, hyaline to yellowish in Melzer's solution; basidia four-spored, 28–34 × 5–6 μ; no pleurocystidia or cheilocystidia seen; gill trama somewhat interwoven, hyaline in KOH, subhymenium thin and more or less cellular; pileus trama loosely interwoven and homogeneous beneath a more compact pellicular layer of slightly narrower cells, pigment mostly intracellular and soluble in KOH; clamp connections present.

Habit, habitat, and distribution.—Gregarious on sandy soil under spruce, Wilderness State Park, near tip of Waugoshance Point, Sept. 7, 1950, Smith 35911, same date, Harry Thiers (Smith 35959), same place, September, 1951, Smith 38553.

Observations.—Apparently this is the first record of this species from the state. Since Kauffman's original description was sketchy, a detailed account is included here. It is a most striking species, with the rivulose pilei and dark colors when mature. The mild odor and taste and darkening colors along with the smooth spores are diagnostic.

6. *Cortinarius elatior* Fries

This is one of the common species of the Pacific Northwest. On all the collections cited here as well as on my western collections (Smith, 1939) clamp connections are consistently absent. The same condition was found on a specimen from Sweden communicated by Lundell, and is true for Kauffman's collections. Thus it would appear that the character is a valuable one. It is easily demonstrated on the gelatinous hyphae of the pellicle. In most species of Myxacium these narrow gelatinous hyphae regularly have clamp connections at the cross walls. However, *Cortinarius elatior* is not the only Myxacium that lacks clamp connections. They are lack-

ing in *C. collinitus* var. *olympianus* Smith (1944), also. Since all other forms and varieties of *C. collinitus* which I have studied have them, it is logical to place var. *olympianus* beside *C. elatior*, where it would rank as an autonomous species by virtue of its lack of cheilocystidia. In addition to this, I have discovered still other variants in the *elatior* group which lack clamps, but a number of details need further study before a critical account of the whole group can be published.

Material reported from Michigan.—Under conifers, Rees's Bog, north shore of Burt Lake, Cheboygan County, Sept. 18, 1949, Smith 33945; Tahquamenon Falls State Park, Sept. 9, 1951, Smith 38628, 38633, 38637; in a bog, east of Burt Lake, Sept. 11, 1951, Smith 38699, 38700.

7. **Hygrophorus laetus** Fr. f. **pallidus**, f. nov.

Pileus albidus; lamellae pallidae, decurrentes, distantes; stipes glutinosus, pallidus. Specimen typicum, in Herb. Univ. Mich. conservatum, A. H. Smith n. 37616, legit prope Pellston, Mich., Aug. 11, 1951 (Harry Thiers).

The microscopic characters all checked with those of forma *laetus*, and the typical disagreeable odor was also present. Young stages were found, and the pallid pileus gills and stipe were characteristic, so that there is no possibility of the carpophores being merely faded fruiting bodies.

8. **Hygrophorus marginatus** var. **concolor**, var. nov.

Pileus concolor cum lamellis. Specimen typicum, in Herb. Univ. Mich. conservatum, legit prope Tahquamenon Falls State Park, Sept. 5, 1949, Smith n. 33324.

Pileus 1–3 cm. broad, conic to obtusely conic, becoming conic-campanulate, surface glabrous, moist and hygrophanous, color "deep chrome" overall, or in some the disc "orange" in buttons, in age "Mars yellow" (brilliant orange yellow), margin finally spreading, thin and striatulate, fading finally to near "apricot-yellow" overall; flesh thin, brittle, concolorous with surface, odor and taste not distinctive; lamellae broad, subdistant, broadly adnate, "capucine yellow" to "deep chrome" (not brighter than pileus); stipe 3–6 cm. long, 4–8 mm. thick, equal or narrowed below, naked and glabrous, moist, "primuline yellow" (clear bright yellow).

Spores 7–9 × 4–5 μ, ellipsoid, smooth; basidia 36–44 × 7–9 μ,

four-spored; no pleurocystidia or cheilocystidia seen; gill trama of short-ellipsoid cells more or less parallel in central strand but flanked by interwoven tissue (subhymenium) on either side; pileus trama with a rudimentary nongelatinous pellicle, tissue of flesh floccose and interwoven; no clamp connections seen.

Habit, habitat, and distribution.—Scattered under hemlock, Tahquamenon Falls State Park, Sept. 5, 1949, Smith 33324 TYPE; same locality, Aug. 6 and Aug. 28, 1951, Smith 37514, 38356.

Observations.—This variety has been somewhat of a puzzle, but collections over a three-year period and comparisons with typical material have shown it to be constant and distinct. In var. *marginatus* the gills are "cadmium orange."

I cannot agree with Singer (1951) in placing this species in Tricholoma or with his statement that "its chemical characters are definitely in favor of insertion in the genus *Tricholoma* rather than *Hygrophorus* (or rather *Hygrocybe*), where it has been placed by Peck and others merely on the basis of the bright colored pigment reminiscent of some *Hygrocybe*, nor does it exactly match any of the colors occurring in that genus." When Singer (1943) made the transfer, he gave as the principal reason the lack of clamp connections in the fruiting body. In my estimation his statement, quoted above, represents his opinion rather than a fact established by adequate research. At least I do not know of sufficient research on the chemical composition of the pigment of the species in question as compared with that on the composition of the pigments of Hygrocybe and Tricholoma generally, to establish it. My own opinion, as one who has seen this fungus and its variations and who has studied them about as much as anyone else, is that its characters, with the exception of the lack of clamp connections, are in line with those of the subgenus Hygrocybe of Hygrophorus. When one considers the three varieties, *marginatus*, *olivaceus*, and *concolor*, it appears obvious that the pigments match those found in Hygrocybe rather than those in Tricholoma. It must always be kept in mind that each species in Hygrocybe has its own peculiar pigment pattern, which is important in the recognition of species. But this was not what Singer referred to when he stated that the pigments do not "match any of the colors occurring in that genus" (Hygrocybe). My own acquaintance with the group forces me to a conclusion just the opposite of Singer's.

Singer recorded an interesting character of *Hygrophorus marginatus* when he pointed out that the species lacked clamp connections. I cannot, however, accept this as sufficient reason for the transfer. As more studies are made on agarics, it is found that in genera characterized by clamp connections at least one or two species turn up which do not have them. I have called attention to this in the present paper for both Cortinarius and Phaeocollybia, and Smith and Morse (1947) commented on it in the *Cantharellus clavatus* stirps. The situation as found in Hygrophorus appears to be a simple parallel to that occurring in these genera. Finally, although I have studied Tricholoma rather extensively in North America, I know of no species with which *H. marginatus* appears to be closely related, whereas in Hygrocybe there are several rather good possibilities, such as *H. coccineus* or *H. amoenus*.

9. *Lactarius Allardii* Coker

Pileus 6–15 cm. broad, convex-depressed, with an incurved margin, broadly vase-shaped in age, often cracked open in the depression, glabrous but with an unpolished to velvety appearance at first, in age at times variously rimose, color dead white at first but soon changing to vinaceous fawn or finally pale brick-red in the depression or more or less overall (changing color first where exposed to light); flesh white, thick, firm, odor faintly pungent, taste acrid and disagreeable (quickly acrid in young caps); lamellae close, narrow, some forked, decurrent, creamy white discoloring to brownish, greenish and then dingy brown where wounded; stipe 1–2 cm. long, 1–3 cm. thick, short, hollow, white and unpolished, becoming colored like the cap overall or in definite areas.

Spores white in deposit, 8–10 × 6–7 μ, broadly ellipsoid, covered with fine dark-violet particles (as warts) as seen in Melzer's solution, the particles separate or connected in groups of a few with fine violet lines (not a complete reticulum); basidia four-spored; pleurocystidia abundant, 50–70 × 9–12 μ, narrowly clavate with short-pointed apices varying to fusoid, often filled with globular (oily) content, tips usually projecting, many filamentous embedded cystidia also present and most with similar content; cheilocystidia similar to pleurocystidia but smaller and at times rare; cuticle of pileus an ochraceous to pallid zone of interwoven narrow hyphae from which arises a dense turf of hyaline narrow (4–6 μ) thick-walled elements

with tapered apices and lacking clamp connections, or these elements grouped into minute cones.

Habit, habitat, and distribution.—Densely gregarious under pine and aspen, University Biological Station, Douglas Lake, Aug. 31, 1951, Smith 38373.

Observations.—This was a common species in the aspens late in August, when *Amanita muscaria* was at the peak of its fruiting cycle. Heretofore it has been considered typical of our southeastern states. It was observed at Douglas Lake during the fall of 1950, also, but only single fruiting bodies were found.

10. *Lactarius paradoxus* Beards. & Burl.

Pileus 6–8 cm. broad, convex-depressed, the margin inrolled at first, glabrous, *viscid*, zonate, "tea-green" to "mineral-gray" or with more blue present, pallid between zones, staining green; flesh thick and firm, pallid with a pea-green tinge, slowly greenish where bruised, odor and taste not distinctive; latex scanty, "sorghum-brown" (dark vinaceous brown), staining the gills green; lamellae "vinaceous buff" but vinaceous red of latex showing at maturity, narrow, close, adnate; stipe 2.5–3 cm. long, about 1 cm. thick, naked, not viscid, concolorous with pileus or bluer, staining green in age, apex dingy vinaceous at line of gill attachment and with a hoary belt below this.

Spores 8–11 × 6–7 μ, ellipsoid, with a varying number of heavy dark-violet lines connected by finer lines to form an irregular reticulum, with inconspicuous warts at junction of heavy lines (mount in Melzer's solution); basidia four-spored; pleurocystidia present only as embedded filaments; cheilocystidia of two types, mostly clavate and 12–20 × 3–8 μ but small fusoid cells 20–30 × 4–6 μ also present in varying numbers; pileus cuticle a thick gelatinous hyaline pellicle of narrow hyphae lacking clamp connections.

Habit, habitat, and distribution.—Single under *Pinus Banksiana* University Biological Station, Douglas Lake, Aug. 31, 1951, Smith 38366; Tahquamenon Falls State Park, Sept. 7, 1951, Smith 38431.

Observations.—This fungus was described as occurring under cabbage palm in grassy places, Fort Christmas, Florida. Consequently its appearance in our northern pine lands during wet years is indeed curious. The diagnostic features of *Lactarius paradoxus*, according to Beardslee and Burlingham (1940), are the grayish-

indigo to smolt-bluish zones, the mahogany-red latex which only slowly becomes peppery and is only slightly bitter, the greenish stains, the vinaceous tinge in the gills (from the latex), and the spores with a reticulum of broad bands. The spores of the Michigan collections thus compare better with the original description of the species than with the "authentic specimen" examined. The taste of my material does not check with the original account of *L. paradoxus*, but in view of the age, condition, and paucity of carpophores available in the fresh state, I prefer to disregard this apparent difference. The characters which indicate identity with the Florida species are the mahogany-red latex, the dingy bluish-green zones of the pileus, and the change to green when bruised. The attempt at a spore print failed.

11. *Lentinus sulcatus* Berk.

Pileus 1–4 cm. broad, obtuse to convex, expanding to plane or disc slightly depressed, margin conspicuously ribbed in young specimens, sometimes the ribs obsolete in age, surface dry and fibrillose, the fibrils becoming aggregated into appressed fascicles or distinct scales (on the margin first but eventually overall), cuticle at first "pecan-brown" or with a grayer cast, becoming "orange cinnamon" to "pinkish cinnamon," or with "cinnamon" scales against a "light pinkish-cinnamon" ground color (various shades of dark to pale vinaceous fulvous); flesh thin, dry, white to pallid, odor slight, taste mild; lamellae bluntly adnate, becoming adnexed, whitish, becoming flushed dingy tan, close, moderately broad, 2 tiers of lamellulae, edges even at first but becoming toothed; stipe 1–3 cm. long, 3–6 mm. thick, equal or base slightly bulbous, solid, pliant, surface fibrillose to fibrillose-striate, basal area somewhat scaly from lacerating cuticle and some shade of incarnate tan, surface above whitish and unpolished to scurfy.

Spores (11) 13–16 (20) × 5.5–7 μ, smooth, thin-walled, elliptic to oblong in face view, slightly bean-shaped in side view, yellowish in Melzer's solution; basidia 30–36 × 7–8 μ, four-spored; pleurocystidia abundant, 60–90 (110) × 7–9 μ, subcylindric, often flexuous, smooth as seen in both KOH and Melzer's solution, the walls hyaline (yellowish in Melzer's solution) and slightly thickened; cheilocystidia similar to pleurocystidia but often smaller and with thinner walls; gill trama subparallel at first but becoming intricately

interwoven, composed of narrow often-branched crooked hyphae with thickened walls, hyaline in KOH and pale yellow in Melzer's solution, a narrow zone of subparallel hyphae flanking the interwoven midsection on each side, basidia arising from hyphae that diverge from outer surface of subparallel zone, no clamp connections seen; pileus trama homogeneous, the hyphae similar to those of central section of gill trama, cuticle differentiated by the hyphae being of slightly larger diameter, having thicker walls, and with colored content when fresh, terminal ends of hyphae often cystidium-like, i.e., clavate to subfusoid and with very thick walls, no clamp connections seen.

Habit, habitat, and distribution.—On dry, decorticated wood, such as aspen logs in exposed places and old fence rails, spring and summer. Clover and Smith collected it at Grousehaven near Lupton, May 17, 1948, Smith 28694, and it was found again in the same locality, May 30, 1951, by Mrs. Lydia K. Frehse, Smith 36334. Paul Harding collected it on cedar (?) fence posts near Umadilla, May 27, 1951, Smith 36317.

Observations.—Murrill (1915) reported it from New York to Indiana and west to Colorado and Montana, and Kauffman (1918) included it in his key but did not report it for the state. No collections by him have been located in the University of Michigan Herbarium. The fungus is very characteristic and can readily be identified in the field by the color of the pileus, which resembles that of *Tricholoma vaccinum*, and by the fact that nearly always the stipes are flattened at the base as a result of the fruiting body originating in a narrow crack in the woody substratum. The large cystidia and yellow reaction of the trama and spores in Melzer's solution are distinctive microscopic characters. Singer (1951) distinguishes between *Lentinus fulvidus* and *L. sulcatus* by the presence of metuloids (pleurocystidia) in the former and their absence in the latter. On this basis, the collections reported here would be *L. fulvidus*. Murrill (1915) considered *L. fulvidus* to be a synonym of *L. sulcatus* and ascribed fusoid cystidia to it.

12. **Mycena alcalina** f. **alba**, f. nov.

Pileus 1–2 cm. latus, obtusus, glaber, albidus demum pallidus; lamellae albidae; stipes albidus. Specimen typicum, in Herb. Univ.

Mich. conservatum, legerunt prope Higgins Lake, Mich., May 17, 1945, A. McCrea et B. B. Kanouse.

Pileus 1–2 cm. broad, obtuse, more or less expanding, surface moist, white, hygrophanous, dead white when faded; flesh thin, white, odor sharp (alkaline); lamellae close, white, ascending-adnate, broad; stipe 2–4 cm. long, 1–2.5 mm. thick, equal, pruinose above, white, glabrous.

Spores ellipsoid, 8–10 (11) × 4.5–6 μ, smooth, bluish in Melzer's solution; basidia 20–26 × 7–8 μ, four-spored; pleurocystidia scattered, (38) 50–70 (80) × 9–14 μ, fusoid-ventricose to subcylindric, the apices rounded to subacute, simple or forked, neck elongating greatly in age and then somewhat irregular in outline; cheilocystidia 28–42 × 9–15 μ, variable, similar to pleurocystidia or subclavate with several to many contorted protuberances projecting from the enlarged portion; gill trama vinaceous in Melzer's solution, of enlarged hyphae with subparallel arrangement; pileus trama with a rudimentary pellicle of hyphae covered by minute rodlike projections or these projections arising from the exposed surfaces of the hypodermal cells, hypoderm distinct, trama, including hypoderm, vinaceous in Melzer's solution.

Habit, habitat, and distribution.—Scattered on a conifer log, Higgins Lake, May 17, 1945, A. McCrea and B. B. Kanouse (TYPE).

Observations.—The cheilocystidia aid in distinguishing this form from *Mycena niveipes*. In addition, the latter occurs on hardwood. The white form of *M. alcalina* was found regularly for several seasons on a log beside Dr. McCrea's cottage, and was constant in the characters as described. In view of this it cannot be interpreted as a chance seasonal variation.

13. Mycena fibula f. alba, f. nov.

Pileus, lamellae, et stipes lacteus. Specimen typicum, in Herb. Univ. Mich. conservatum, legit prope Cross Village, Mich., July 21, 1947, Smith n. 25859.

Pileus 1.5–3 mm. broad, obtusely conic to convex, becoming somewhat campanulate or flaring on the margin, surface moist and hygrophanous, milk-white fading to a dead white and eventually discoloring to yellowish, surface at first minutely hispid (under a lens) from numerous pilocystidia, only very faintly striatulate

when moist; flesh thin, fragile, no odor or taste; lamellae broad, arcuate to decurrent, subdistant to distant, white, unchanging, very finely pruinose under a lens; stipe 10–15 mm. long, 0.25–0.5 mm. in diam., equal, fragile, concolorous with pileus and gills, unchanging when bruised, surface evenly and finely pubescent overall (under a lens), base faintly fibrillose.

Spores 4.5–5.5 (6) × 2.8–3.2 μ, smooth, oblong or nearly so, hyaline, thin-walled when fresh, but as revived after drying having a thickened wall, nonamyloid; basidia four-spored, 18–24 × 4–5 μ; pleurocystidia scattered, 60–80 × 9–14 μ, ventricose with long neck and subcapitate apex or apex not enlarged, thin-walled or, as revived in Melzer's solution, with a slight thickening in the apex, hyaline; cheilocystidia rare to scattered, similar to pleurocystidia; gill trama interwoven, nonamyloid; pileus trama nonamyloid, homogeneous (evenly cellular in tangential sections), with numerous pilocystidia similar to pleurocystidia arising from among the surface hyphae, clamp connections present but difficult to demonstrate.

Habit, habitat, and distribution.—Gregarious on a mossy bank in a hardwood forest, Cross Village, July 21, 1947, Smith 25859.

Observations.—In aspect this form does not suggest *Mycena fibula* f. *fibula*, but the spores as well as the cystidia of gills, pileus, and stipe are identical or at most merely vary slightly in size. Consequently it seems best to refer it to *M. fibula* as a form with a typical Mycena-like pileus and lack of pigment. With this form in mind the transition from the Mycena type of pileus to the Omphalina type is readily understood.

14. **Mycena Leaiana** f. **pallida**, f. nov.

Pileus 1–3 cm. latus, pallidus, viscidus; lamellae obscure luteomarginatae; stipes viscidus, pallidus vel subluteus. Specimen typicum, in Herb. Univ. Mich. conservatum, legit prope Proud Lake, Oakland Co., June 4, 1951, Smith n. 36340.

Pileus 1–3 cm. broad, obtuse to broadly convex, expanding to nearly plane, surface glabrous, viscid, faintly striate, color gray to pallid or brownish in age or then with dingy reddish-brown areas, drying pallid to gray; lamellae broad, close to subdistant, broadly adnate, pallid to dingy cream color but edges dingy yellow; stipe 3–7 cm. long, 2–3.5 mm. thick, equal, viscid, glabrous, pallid to dingy yellowish, often drying grayish at base.

Spores 8–10 × 5–5.5 μ, blue in iodine (amyloid), smooth, elliptic in face view, many slightly bean-shaped in side view; basidia four-spored, 20–24 × 7–9 μ; pleurocystidia 34–48 × 9–12 μ, fusoid-ventricose to mucronate, smooth, pale yellow in H_2O when fresh, hyaline or nearly so when revived in KOH; cheilocystidia similar to pleurocystidia or generally less ventricose, with yellow content at first; gill trama orange brown in Melzer's solution except for the conspicuously gelatinous subhymenium of interwoven narrow hyphae; pileus trama with a thick gelatinous pellicle, tissue beneath orange brown in Melzer's solution, hypoderm poorly differentiated; clamp connections present.

Habit, habitat, and distribution.—Cespitose on beech logs, Proud Lake Recreation Area, Oakland County, June 4, 1951, Smith 36340 TYPE.

Observations.—This form was found growing in association with f. *Leaiana* on a windfall of several trees. It was clearly a form with very little pigment, rather than faded clusters of otherwise typical material. Both were in fresh, rapidly growing condition, and all stages of development from buttons to old caps were present in both, so that they could be compared. The existence of such a form as this is especially interesting in view of the discussion given under *Mycena mackinawensis.*

15. **Mycena mackinawensis**, sp. nov.

Pileus 10–20 (25) mm. latus, convexus vel subdepressus, glaber, udus demum viscidus, pelliculosus, fuligineus; lamellae pallidae vel cinereae, breviter decurrentes, subdistantes; stipes 1–2.5 cm. longus, 1–2 mm. crassus, viscidus, sursum pallidus, deorsum fuligineus; sporae 8–10 (11) × 5–5.5 μ vel 7–9 × 3.5–4 μ; pleurocystidia 30–45 × 8–13 μ, fusoideo-ventricosa; cheilocystidia filamentosa vel clavata et verrucosa. Specimen typicum, in Herb. Univ. Mich. conservatum, prope University Biological Station, Douglas Lake, Mich., June 30, 1947, Smith n. 25346.

Pileus 10–20 (25) mm. broad, when young convex to flattened, nearly plane or with an abruptly decurved margin at times and sometimes with a depressed disc, surface moist at first but soon viscid to the touch, pellicle thick and separable, color near "drab gray" when young, at maturity "grayish olive" on disc and with a paler margin, strongly translucent-striate to disc when moist, staining

reddish in age; flesh thin, pliant, no distinctive odor, taste not recorded; lamellae whitish when young, then gray but paler than pileus, arcuate, becoming short-decurrent, subdistant, only moderately broad, edges even; stipe 1–2.5 cm. long, 1–2 mm. thick, equal, nearly concolorous with pileus or paler above and concolorous below, pruinose, viscid, sparsely white-strigose at base.

Spores 8–10 (11) × 5–5.5 μ when revived in KOH, 7–9 × 3.5–4 μ in fresh material, when fresh pale blue in Melzer's solution, darker blue when revived in herbarium after drying, smooth, subellipsoid; basidia both two- and four-spored; pleurocystidia rare to scattered, 30–45 × 8–13 μ, essentially fusoid-ventricose and arising in the subhymenium, smooth or with one or more bumps or short projections, some branched at or near apex, in most the ventricose portion above the midpoint and narrowed evenly to an obtuse to subacute apex, without an appreciable neck, hyaline, thin-walled, not staining in Melzer's solution; cheilocystidia filamentous and contorted or clavate and covered with minute rods or warts (all degrees of variation present); gill edges beneath cystidia gelatinous; gill trama yellow to orange brown in iodine, of enlarged cells somewhat interwoven, subhymenium gelatinous and filamentous-interwoven; pileus trama with a thick gelatinous pellicle, the surface of which is covered by a thin layer of nongelatinous strongly diverticulate hyphae and with intermingled cells resembling the cheilocystidia, the arrangement of the gelatinous hyphae beneath this layer more or less vertical to surface of pileus; clamp connections present.

Habit, habitat, and distribution.—Single or in groups of 2–3 on dead branches of conifers, summer and fall. It is known from the Douglas Lake region as well as from the Rifle River area of the Conservation Department at Lupton.

Observations.—This is a dark-gray to olivaceous-gray or pallid fungus most closely resembling *Mycena vulgaris* in appearance, but differing in having somewhat fusoid pleurocystidia and a habitat definitely on dead branches and sticks of conifer wood, that is, truly lignicolous. It is closest to *M. pelliculosa* but differs in being distinctly lignicolous and in having pleurocystidia of only one type, that is, fusoid-ventricose. From information available, *M. Austini* is a white fungus with narrower pleurocystidia and cheilocystidia similar to pleurocystidia—whether or not it is truly distinct from the cespitose southern *M. glutinosa* is somewhat questionable.

The interesting feature in regard to *Mycena mackinawensis* is that it helps to fill in a series of distinct taxa starting with *M. vulgaris* and ending in *M. Leaiana*. At first glance it appears utterly ridiculous to suggest a true relationship between them. If, however, we assume that established morphological differences are less subject to change in the process of evolution than physiological differences, we have the following situation: The spores are about alike in all, the structure of the pileus, gills, and stipe is very similar, and the various types and arrangements of cystidia are ordinary for the genus. The changes which have occurred are in the shape and distribution of the cystidia, but, again, even these are ordinary for Mycena, and a similar pattern of change is present in nearly every section of the genus, and it does not appear to be correlated with color or manner of growth.

The species are also similar in the pigments, progressing from the fuliginous type to the leuco type (lack of color) and then to the yellow to orange types. All these are intracellular. The enzyme systems have changed slightly at least, to the extent that a fungus capable of living on needle beds under conifers has given rise to types which survive best on the actual wood of conifers, and these in turn have given rise to types which do best on the wood of hardwoods or are limited to that substratum. The fascinating features of the problem are that here we have, in our flora, taxa representing all the important stages in this supposed evolutionary sequence, and that the majority of the taxa are endemic to North America. We have, as a starting point, *Mycena vulgaris*, circumpolar in distribution and inhabiting needle beds under conifers. Then comes *M. mackinawensis*, very similar to *M. vulgaris* in all characters except habitat (wood of conifers) and the presence of a certain type of pleurocystidium. The cheilocystidia are not sufficiently different to be a reliable species character, and the degree of gelatinization of the gill edge is in the same category. From *M. mackinawensis* we go to *M. Austini*, which is still on wood of conifers, but is white (lacking pigment) and with cheilocystidia different from those in the species named above. *M. glutinosa* may be only a southern cespitose variety of *M. Austini*, which has gone over to hardwood. At this point we find *M. euspeirea* and *M. texensis* differing in characters of pigment from *M. glutinosa*. *M. euspeirea* is fuliginous, and *M. texensis* is apparently so, but with a tendency to yellow in age or

when drying. These differ from *M. Leaiana* f. *pallida* in minor characters, such as lack of pale yellow gill edges and slight differences in cystidia. The habitat remains essentially the same. Finally, at the end of this line from *M. vulgaris* we have *M. Leaiana* f. *Leaiana*, with brilliant orange pileus, orange gill edges, and growing clustered on hardwood logs. The geographical evidence points to the conclusion that evolution has been from the species with wide distribution (*M. vulgaris*) to those of limited distribution.

16. *Phaeocollybia Christinae* (Fr.) Heim

This fungus is beautifully illustrated in Icones Farlowianae, Pl. 53. 1928. The Tahquamenon collection checked exceedingly well macroscopically with this plate, and the spore size is that reported for American material. A detailed account of the microscopic characters of Smith 38033 is given here for comparison with the other species.

Spores 8–10 × 4.5–5 μ, ovate in face view, in side view inequilateral, very minutely roughened, rusty ochraceous in KOH; basidia hyaline in KOH, four-spored, 20–26 × 5.5–7 μ; no pleurocystidia; cheilocystidia fusoid to hairlike or subcapitate, 20–30 × 4–6 μ; gill edge with many fertile basidia; gill trama weakly ochraceous to hyaline in KOH, the hyphae parallel and with short-cylindric cells, subhymenium inconspicuous; pileus trama with a well-developed gelatinous pellicle of smooth hyaline hyphae 3–4.5 μ in diam., the area beneath of compactly arranged incrusted hyphae of larger diameter, the flesh proper floccose-interwoven and nearly hyaline; clamp connections absent.

Habit, habitat, and distribution.—Gregarious under hemlock and hardwoods, Lower Falls, Tahquamenon Falls State Park, Aug. 20, 1951, Smith 38033.

Observations.—Singer (1951, p. 566) remarks of Phaeocollybia: "... all hyphae with clamp connections." This is not at all true of my collection. After a diligent search I failed to find a single clamp or indication of one. But there cannot be the slightest doubt that the fungus is a typical Phaeocollybia in all its other characters. If European material has clamped hyphae and possibly slightly different spores, as some descriptions and Singer's statement might indicate, there may be reason to regard the Tahquamenon collection as representing a new species.

17. *Phaeocollybia Jenniae* (Karst.) Romagnesi

(Pl. III)

Pileus 1–3 cm. broad, broadly conic with an inrolled margin, becoming plano-umbonate, the umbo conic, glabrous, *viscid*, near "chestnut" (deep ferruginous red) fading to "burnt sienna" (ferruginous) and finally a paler orange tan, hygrophanous; flesh thickish, firm, cartilaginous, bitter; lamellae close to crowded, narrow, adnexed, dingy ochraceous when young, cinnamon in age, edges even; stipe 5–9 cm. long, 2.5–4 mm. thick at apex, narrowed downward into a tapered pseudorhiza, about concolorous with pileus (ferruginous red) but darkening to deep purple brown from the base up, extreme apex pallid tan to brownish.

Spores 5–6.5 × 3.2–3.7 μ, ellipsoid to subovoid, in side view with a slight suprahilar depression, ochraceous in KOH and in Melzer's solution, slightly roughened (use oil immersion); basidia four-spored, 19–23 × 4.5–5.5 μ; no pleurocystidia; cheilocystidia rare to scattered, 18–24 × 3–5 μ, hairlike to narrowly fusoid, hyaline; gill trama parallel, of short-cylindric cells, hyaline or nearly so in KOH, subhymenium inconspicuous; pileus trama homogeneous and interwoven beneath a pellicle of narrow radial hyphae with ochraceous pigment incrusted on the walls (as revived in KOH), these hyphae subgelatinous on surface of cap, nongelatinous below; no clamp connections seen.

Habit, habitat, and distribution.—Gregarious under Pteridium near an old pine stump in very sandy soil, Tahquamenon Falls State Park, at the Lower Falls, July 16, 1951, coll. Chester Leathers (Smith 36892), and again July 23 (Smith 37092).

Observations.—A careful search was made for clamp connections on this species, also, but none were found. No record of the odor was made, but the taste may indicate that the Tahquamenon collections represent a distinct taxa. Lange's illustration (1939) depicts our collections very well, but he did not give data on odor or taste. *Phaeocollybia Jenniae* is very close to *P. radicata* (Murr.) Singer, but the latter, according to my notes, lacks a bitter taste and has paler smoother spores. In addition, clamp connections are present in *P. radicata*. *P. attenuata* (Smith) Singer has larger spores than are found in either *P. Jenniae* or *P. radicata*, and different colors.

18. **Rhodophyllus luteus** (Pk.), comb. nov.

Single on a conifer log, Mud Lake Bog, Cheboygan County, July 25, 1946, coll. Travis E. Brooks, n. 1311; Wolf Bog hardwoods, Cheboygan County, Aug. 28, 1946, Smith 22333. Smith and Wehmeyer (1936) gave a description based on collections from Nova Scotia. This species is closely related to *Rhodophyllus Murraii* (B. & C.) Singer and *R. salmoneus* (Pk.) Singer by the quadrate spores, but the colors distinguish it from both. Since there seems to be a difference of opinion whether "Rhodophyllis," the name of an algal genus, is just a variant spelling of "Rhodophyllus," I shall continue to use the latter name.

19. *Russula ventricosipes* Peck

(Pl. IV)

Pileus 6–12 (15) cm. broad, convex, expanding to nearly plane or slightly depressed over the disc and with a spreading margin, surface viscid and glabrous or cuticle cracked to form areolae near margin, margin even (scarcely a trace of tuberculate striae in even the oldest specimens), when young cinnabar-red over marginal area and the disc "bister," the red soon disappearing and brown fading to "clay color," "cinnamon-buff," or, in age, sometimes pinkish buff (clay color, dark to pale); flesh thick, firm, hard, whitish but where broken with a faint reflection of sulphur developing, taste slowly burning-acrid, odor strong and similar to that of *Russula foetans;* lamellae close, broad, adnate, some forked, "ivory-yellow" (whitish) when young, soon stained dingy ochraceous and finally sordid brown, margin often brown from staining, in buttons beaded with drops and at this stage edges may be cinnabar-red; stipe 4–8 cm. long, 1.5–3 cm. thick, often ventricose and narrowed at base, solid, *firm* and *hard*, surface dingy pallid but splashed variously with cinnabar-red, lower portion entirely cinnabar-red, staining sulphur-yellow in base when broken, cortex staining yellow when cut.

Spores "warm buff" in a good deposit (E of Crawshay's scale), 8–10 × 4.5–5 μ, ellipsoid, in Melzer's solution seen to be covered with minute dark violet warts (more numerous at apex) and granules (much as in Melanoleuca); basidia 60–70 × 8–10 μ, four-spored; pleurocystidia abundant (as pseudocystidia), embedded in hyme-

nium, 50–80 × 6–12 μ, and more or less fusoid; cheilocystidia clavate to subfusoid, 38–50 × 6–9 μ, some brownish in Melzer's solution; pileus trama a thick turf or tangled mass of narrow hyaline gelatinous hyphae (in KOH).

Habit, habitat, and distribution.—Gregarious under *Pinus Banksiana* on sand dunes, Whitefish Point, Sept. 7, 1951, Smith 38422, Sept. 9, Smith 38676.

Observations.—This is a most unusual species of Russula in many respects. In fully half the carpophores collected (about two bushels) the cap never pushed through the sand far enough to expose the gills. We regularly located specimens by spotting the humps in the sand. The cinnabar-red stains are, of course, striking, and ellipsoid Melanoleuca-like spores are most unusual. Singer (1942) published a lengthy account of this fungus and commented on the spore characters. However, he gave the spore print as color B (in text) and color C (in footnote) of Crawshay's chart. In the prints I obtained the color was E of the Crawshay scale, a very striking difference. The odor in our collections also differed markedly from the odor as Singer described it. In ours the odor was just like that of *Russula foetans* and was fully as strong. Singer did not mention the change to yellow in the base of the stipe when cut, and did not sufficiently emphasize that the gills and stipe readily stain brown without the application of any chemicals. We did not look for spores in the hypogeous specimens, but the red tints and exuding droplets were very pronounced. Because of the sand adhering to the pellicle it is almost impossible to section. We did not obtain the chemical characters of the fresh material, and so our collections cannot be compared with Singer's on that basis. Consequently we are merely pointing out the differences here as a guide to further field work. If one is not careful when dealing with such a rare fungus as this, each new record will be described as a new form or variety simply because the range of variation is difficult to establish.

PART II

The North American Species of Xeromphalina Kühner & Maire

In the most recent discussion of the genus Xeromphalina, Singer (1951) has limited it to three species, *X. campanella*, *X. cauticinalis*,

and *X. orickiana*. The genus Heimiomyces is considered distinct largely on the structure of the cuticle. This concept maintains a grouping of Marasmius-like fungi with "amyloid" (bluish in Melzer's solution) spores, which obviously brings taxa together in a way that is both practical from the standpoint of one who uses a work purely for purposes of identification and satisfactory to one who insists that a classification express relationships, i.e., a natural classification.

The genus has interested me for a long time because one of the fungi which I collected during my summer with Kauffman was a species in this genus growing on oak stumps. Kauffman was puzzled by it, but had known it for some time from other collections. Singer (1951) mentioned what seems to be this fungus, but did not give it a name. It appears quite regularly during late spring and early summer, but because it is very close to *Xeromphalina campanella*, I, like Kauffman, have hesitated to do anything with it. During the last twenty years, however, a number of other taxa in this genus have come to light, so that the time seems appropriate to publish a summary of my findings.

The puzzling species on oak is here described as *Xeromphalina Kauffmanii*. In it the pileus and gill trama are composed of hyphae with somewhat thickened walls, which are slightly refractive in KOH but not strikingly so. This character is, however, a pronounced feature of the species of Heimiomyces Singer (*H. tenuipes* and *H. fulvipes*). Since both of these are well known to me, a critical comparison has been made with the species of Xeromphalina, and I am now convinced that the best expression of relationships is arrived at by grouping all these species in one genus, for which Xeromphalina is the oldest name. *H. fulvipes* (*Collybia fulvipes* Murrill) has a practically glabrous pileus and, actually, in my studies, I have failed to demonstrate any thick-walled colored pilocystidia. On the basis of Singer's 1951 separation, then, *X. orickiana* is more typical of Heimiomyces than of Xeromphalina, where he placed it, and *H. fulvipes* is a better Xeromphalina. I was at first inclined to regard the subgelatinous nature of the walls of the hyphae of the gill trama and pileus trama (in KOH) as the deciding character between the two genera, but with this character present to some degree in *X. Kauffmanii*, it seems better to regard the species of Heimiomyces as a section of Xeromphalina in which the tramal character has become accentuated.

EMENDED DIAGNOSIS OF XEROMPHALINA KÜHNER & MAIRE

Fruiting bodies with the aspect of Marasmius, mostly with broadly adnate to decurrent gills, intercellular often incrusted pigments, spores bluish in Melzer's solution, stipe with tawny pubescence or pruinosity extending upward in most species and with fulvous mycelium often very conspicuous over the base, pileus margin usually incurved, trama of gills and pileus with slightly thickened to distinctly thickened highly refractive walls (as revived in KOH).

Type species.—*Agaricus campanellus* Fr. *Syst. Myc.*, 1: 166. 1821.

The genus is distinguished from Omphalina by the more horny (Marasmius-like) consistency of the stipe, and the bluish spores as seen in Melzer's solution. This last character also distinguishes it from Flammulina Karsten (*Collybia velutipes*), which has a stipe covered by a velvety coating of tan to fulvous or blackish-brown hairs.

KEY TO SECTIONS AND SUBSECTIONS

A. Trama of gills and pileus with hyphae thickened and rather highly refractive (revive in KOH) ..... Section Heimiomyces

A. Trama of gills and pileus with thin-walled hyphae (slightly thickened and refractive in *Xeromphalina Kauffmanii*), which are often heavily incrusted with pigment ..... Section Euxeromphalina

1. Cheilocystidia clavate-echinulate ..... Subsection Pictae

1. Not as above 2

2. Pileus trama dark vinaceous brown in KOH; thick-walled pilocystidia present ..... Subsection Orickianae

2. Not as above 3

3. Pileus trama turning red in KOH ..... Subsection Mutabiles

3. Pileus trama merely brownish to ochraceous in KOH Subsection Campanellae

FIELD KEY TO SPECIES

1. Pileus dark vinaceous brown; known only from redwood logs and stumps 6. *X. orickiana*

1. Pileus some other color; substrata various 2

2. Stipe swollen at apex and gills attached to the swelling by their inner margins 1. *X. picta*

2. Gill attachment normal; stipe apex not abruptly enlarged 3

3. Pileus dry and velvety from dense covering of pilocystidia .. 7. *X. tenuipes*

3. Pileus glabrous or merely somewhat pruinose to unpolished 4

4. Typically densely cespitose-gregarious on wood 5
4. Typically gregarious to scattered or only in clusters of a few fruiting bodies; substrata various 6

5. On wood of conifers ..... 4. *X. campanella*
5. On wood of oak (possibly other hardwoods) ..... 5. *X. Kauffmanii*

6. Taste bitterish; aspect collybioid ..... 8. *X. fulvipes*
6. Taste mild; aspect omphalioid 7

7. In sphagnum bogs, on needle beds or on debris under conifers on the forest floor ..... 2. *X. cauticinalis*
7. On debris of ash or on humus under ash (Fraxinus) .... 3. *X. fraxinophila*

SECTION EUXEROMPHALINA

Hyphae of the pileus and gill trama with thin to slightly thickened walls, which, as revived in KOH, are not refractive or only slightly so; aspect of fruiting bodies omphalioid.

Subsection **Pictae**, subsec. nov. Cheilocystidia clavato-echinulata. Stipe apex swollen and gills attached by their inner margin to this swelling in the only species known from our area.

1. Xeromphalina picta (Fr.), comb. nov.

Agaricus pictus Fries, Syst. Myc., 1: 166. 1821.
Omphalia picta Gillet, Les Hyménomycètes, p. 299. 1878.

Pileus 2–5 mm. broad, 5–10 mm. high, cylindric or with a flaring margin, not expanding, the disc flattened and circumscribed by a dark line, distinctly striate to the disc, glabrous, moist, "Brussel's brown" over the disc and striae, the remainder yellowish; flesh very thin, yellowish to brownish under the disc, odor not distinctive, taste slight; lamellae subdistant to distant (15–18 reach the stipe), only one tier, narrow, attached to the enlarged upper part of the stipe by their inner margins (the only free portion of the margin is that between the stipe and the margin of the pileus, actually only the outer extremity of the gill), color near "warm buff" (yellow); stipe 2–6 cm. long, filiform or up to 1 mm. thick, apex abruptly inflated (2.5 mm. for a distance as long as the pileus is high), equal below, very rigid, cartilaginous, glabrous, concolorous with the pileus, with sparse tawny mycelium around the base.

Spores (7) 8–10 (11) × 4–5 (5.5) μ, ellipsoid to subovoid (immature spores may appear broadly fusoid), pale gray blue in Melzer's

solution; basidia four-spored, 16–18 (20) × 8–10 μ, hyaline in KOH, yellowish in Melzer's solution; no pleurocystidia seen; cheilocystidia 15–20 × 10–14 μ, clavate to broadly ellipsoid, apices studded with short rodlike projections; gill trama of irregular enlarged hyphae dingy brown to ochraceous in KOH, subhymenium cellular but elements smaller than in trama proper, in Melzer's solution pale orange brown, especially in the central portion; pileus trama with a hypoderm of greatly enlarged cells staining rusty red in Melzer's solution and a lower narrow zone similar to gill trama, in small caps the lower zone reduced to a subhymenial zone, in KOH merely ochraceous, a thin rudimentary pellicle (ochraceous in KOH) covering the surface at least in large caps.

Habit, habitat, and distribution.—Gregarious to subcespitose or solitary at times, on rich humus in dense forests or thickets, Tennessee, Michigan, and Washington, summer and fall, rare.

Observations.—This species was reported by Smith and Hesler (1940) from the Great Smoky Mountains National Park and the State of Washington. Since this report it was found on a number of occasions in the Mt. Rainier National Park, Washington (Smith 28959, 29138, 30246, 30563, 30574, 30577, and Imshaug 1233, 2057), in the summer and fall of 1948. During the season of 1951 it was discovered in Michigan at the Tahquamenon Falls State Park, Luce County, July 9, by Miss Sheila Hoare (Smith 36796).

The study of numerous collections in the fresh condition has served to emphasize the similarity to *Xeromphalina campanella* in its major characters. The almost horny consistency of the stipe, the tawny hairs at the base, and the aspect of the pileus indicate a true relationship. The cheilocystidia, of course, are quite different.

Subsection **Mutabiles**, subsec. nov. Trama pilei in KOH flameotincta. Carpophores gregarious or scattered or merely subcespitose; terrestrial or on debris on forest floor.

2. *Xeromphalina cauticinalis* (Fr.) Kühner & Maire

Bull. Soc. Myc. France, 50: 18. 1934

(Pl. V, Fig. 1)

Marasmius cauticinalis With. ex Fries, Epicr. Syst. Myc., p. 383. 1838.
Omphalia pubescentipes Peck, Bull. Torrey Bot. Club, 24: 141. 1897.
Omphalia parvibulbosa Kauff. & Smith, Pap. Mich. Acad. Sci., Arts, and Letters, 17: 190. 1933.

Marasmius fulvobulbillosus R. Fries, Göteborgs kungl. vetenskaps- och vitterhetssamhälles Handlingar, Fjärde Följden, 3: 28. 1901.

Pileus (5) 10–25 mm. broad, convex with a slightly incurved margin, sometimes papillate, often becoming flattened-campanulate or with a small central abrupt depression, sometimes rugose in the depression, margin becoming slightly sulcate-striate to irregular or crenate, in age sometimes lacerate, at first often hoary-pruinose, with a pallid to yellowish pruinosity, soon naked, color "russet" to tawny or ochraceous tawny, when faded and old near "warm buff" (yellow), sometimes staining ferruginous in age; flesh very thin and pliant, concolorous with pileus and fading with it, odor and taste not distinctive; lamellae close to subdistant (15–20 reach the stipe), 1–2 tiers of lamellulae, narrow, moderately broad in age (about 1.5 mm.), broadly adnate becoming short-decurrent, a few forked near the stipe, many forked near cap margin, pale yellow ("Naples yellow"), or a dingy yellow, strongly intervenose; stipe (2) 3.5–8 cm. long, 1–2.5 mm. thick at apex, equal above a small bulb coated with a tawny mass of mycelium and debris often quite firmly held by the hairs, pliant, tubular, date-brown to dark brown or bay below, pale tawny to ochraceous above, covered overall by a rusty pubescence or pruinose coating.

Spores 5.5–7 × 3–4 μ, ellipsoid, immature spores dark violet in Melzer's solution and minutely roughened, smooth at maturity; basidia four-spored, 26–32 × 5.5–7 μ, hyaline in KOH; no pleurocystidia; cheilocystidia rare to scattered, 26–30 × 4–7 μ, subcylindric to slightly ventricose, the apex obtuse to subacute, forked in some, occasionally contorted above; gill trama rose-red to orange red in KOH; pileus trama with a pellicle appearing cellular in tangential section (hyphae radially arranged), tissue beneath intricately interwoven and both orange red in KOH; clamp connections present.

Habit, habitat, and distribution.—Gregarious to scattered under conifers, in sphagnum bogs, and on very decayed wood of pine and Douglas fir, especially where this is found as debris on the forest floor. It is actually a common species in the northern Rocky Mountains and along our Pacific coast. It appears, however, to be rare to uncommon in Michigan, where it fruits mostly during wet seasons.

Observations.—This is a much-named fungus, but when once well known, an easy one to recognize in the field. The cheilocystidia

are generally rare and not of much value as a taxonomic character so far as their presence or their absence is concerned. There is an aspect which distinguishes it from all the specimens of *Xeromphalina fraxinophila* I have seen, but which it is hard to put into words.

3. **Xeromphalina fraxinophila**, sp. nov.

Pileus 10–30 mm. latus, subspadiceus demum dilute fulvus, glaber: lamellae adnatae vel subdecurrentes, confertae, melleae; stipes 5–7 cm. longus, 2–3.5 mm. crassus, deorsum fulvo-strigosus; sporae 4.5–5.5 (6) × 2.5–3.3 μ. Specimen typicum, in Herb. Univ. Mich. conservatum, ad ligna Fraxini prope Kent Lake, Oct. 2, 1945, Smith n. 20902.

Pileus 10–30 mm. broad, broadly convex with an incurved margin, soon umbilicate and margin arched or finally spreading, sometimes wavy to crenate, surface moist but faintly hoary in buttons, hygrophanous, "bister" at first, gradually paler and finally ochraceous tawny on the margin, becoming dingy ochraceous tawny to dark buckthorn brown over disc, margin closely striatulate when moist, surface often concentrically zoned in age; flesh concolorous with surface, thin and pliant, odor and taste not distinctive; lamellae "honey-yellow," narrow, adnate to subdecurrent, close to nearly crowded, 2 tiers of lamellulae, often intervenose, edges even; stipe 5–7 cm. long, 2–3.5 mm. thick, equal or enlarged slightly either way, evenly brownish pubescent overall and base with conspicuous tawny-yellow matted tomentum, apex orange brown, lower portion dark reddish brown beneath the pubescence.

Spores 4.5–5.5 (6) × 2.5–3.3 μ, white in deposit, pale gray blue in Melzer's solution, smooth or immature spores very minutely roughened, ellipsoid; basidia four-spored, 26–30 × 5–6.5 μ, hyaline in KOH; no pleurocystidia or cheilocystidia seen; gill trama yellow in water mounts of fresh material (pigment in the wall), in Melzer's solution yellowish, in KOH bright pinkish red fading to orange brown, interwoven, subhymenium narrow, compactly interwoven; pileus trama with a well-formed nongelatinous cuticle of radial hyphae having cells slightly broader than those of flesh proper (cuticle appearing cellular in tangential sections), cuticle and flesh red in KOH and fading to orange brown; clamp connections present.

Habit, habitat, and distribution.—Gregarious-subcespitose on de-

bris of Fraxinus—branches, rotten logs almost reduced to humus, and old leaves—and at times on humus under these trees. Kent Lake, Oakland County, Mich., Oct. 2, 1945, Smith 20902 TYPE, 20903, Oct. 4, 1945, Smith 21051.

Observations.—This species is clearly in the same subsection as *Xeromphalina cauticinalis*. The color of the button stages is quite different, being a dingy yellow brown in the one on ash and a rich rusty brown in *X. cauticinalis*. The type locality has been cleared and is now part of the bottom of Kent Lake, so that there is no chance of collecting this fungus again in the type locality.

Subsection **Campanellae** (Singer), comb. nov. Pileus trama not becoming red or vinaceous in KOH; carpophores typically cespitose-gregarious on wood, pilocystidia rare and mostly near the margin on young pilei; pleurocystidia and cheilocystidia, when present, smooth and fusoid-ventricose.

4. *Xeromphalina campanella* (Fr.) Kühner & Maire

Bull. Soc. Myc. Fr., 50: 18. 1934

(Pl. VI)

Agaricus campanella Fries, Syst. Myc., 1: 166. 1821.
Omphalia campanella Kummer, Führer in die Pilzk., p. 107. 1871.
Omphalina campanella Quélet, Enchir. Fung., p. 45. 1886.
Omphalopsis campanella Earle, Bull. N. Y. Bot. Gard., 5: 425. 1909.

Pileus (5) 10–25 mm. broad, convex when young, becoming broadly convex to plane and soon developing a depressed disc, surface glabrous and moist, opaque at first, becoming striate before losing moisture and fading, the margin curved in slightly at first but soon straight, color dull orange yellow to tawny, the margin near "yellow ocher" at first and the disc "ochraceous tawny," becoming darker tawny in age and finally tawny or near "cinnamon-brown" overall, sometimes "yellow ocher" overall when young and becoming "clay color"; flesh thin and somewhat pliant, yellow, odor and taste not distinctive; lamellae arcuate-adnate at first, becoming deeply decurrent, thickish, intervenose, subdistant, narrow, tapering to margin of cap, pruinose; stipe 1–4 (5) cm. long, 1–2 mm. thick, with a small tubule, curved or straight, more or less yellow ocher overall at first and covered by a yellowish pruina, becoming glabrous

near apex, base becoming strigose from tawny to fulvous mycelial hairs, horny-cartilaginous in texture and darkening from the base upward in age, finally almost date-brown overall except the apex.

Spores 6–7.5 × 3–3.5 μ, hyaline, smooth, bluish in Melzer's solution, narrowly ellipsoid to subcylindric; basidia four-spored, (22) 24–28 × 5–5.5 μ; pleurocystidia scattered, ventricose to subcylindric, thin-walled and smooth, 26–40 × 8–14 μ, apices obtuse, contents hyaline; cheilocystidia similar to pleurocystidia but more abundant; gill trama of interwoven brown-walled (revived in KOH) hyphae; pileus trama homogeneous, hyphae brown-walled in KOH, and those over the surface slightly gelatinous; clamp connections present.

Habit, habitat, and distribution.—Gregarious to cespitose on decaying conifer wood throughout the United States and Canada. Common and abundant from spring to winter, depending on weather conditions. Along our Pacific coast it can be found during the winter months as well.

Observations.—Little need be said of this well-known fungus. It is described and illustrated in most mushroom books under the name "*Omphalia campanella.*" As Singer (1951) points out, it can be used as an indicator for conifer wood, an item of some importance since the logs upon which it grows are often moss-covered and in advanced stages of decay. In regions where oak is present, however, *Xeromphalina Kauffmanii* may be expected.

5. **Xeromphalina Kauffmanii**, sp. nov.

(Pl. V, Fig. 2)

Pileus 5–25 mm. latus, convexus, demum subinfundibuliformis, ferruginus demum fulvus; lamellae latae, subdistantes, angustae, decurrentes; stipes 1–4 cm. longus, 1–2 mm. crassus, ferruginus; sporae 5–6 × 3–3.3 μ. Specimen typicum, in Herb. Univ. Mich. conservatum; ad ligna Querci, Chelsea, Mich., June 29, 1940, Smith n. 15156.

Pileus 5–25 mm. broad, broadly convex at first, soon with a slight depression at the center and plane to the decurved margin, in age the margin becoming elevated at times and then shape more funnel-like, margin incurved at very first, surface glabrous, color "cinnamon rufous" to "hazel" when young (bright ferruginous),

margin soon yellowish and striatulate, fading slowly (as if subhygrophanous) to dingy yellowish; flesh thin, odor and taste not distinctive; lamellae close to subdistant, narrow, decurrent, near "ochraceous buff" (pale yellow), strongly intervenose; stipe 1–4 cm. long, 1–2 mm. thick, enlarged above, ferruginous above ("cinnamon rufous"), darker red brown below ("Kaiser brown" to "liver-brown"), minutely and evenly pubescent at first, in age glabrous above, somewhat horny in consistency, with rusty-brown to tawny-brown mycelium at base.

Spores 5–6 × 3–3.3 μ, ellipsoid, gray blue in Melzer's solution, smooth at maturity but when immature indistinctly roughened with minute granules which turn bluish in Melzer's solution, basidia four-spored, hyaline in KOH; pleurocystidia and cheilocystidia similar, scattered, 40–70 × 8–12 μ, narrowly fusoid-ventricose to subcylindric, apices obtuse, hyaline, smooth; gill trama ochraceous to slightly darker and with a thin nongelatinous pellicle of narrow hyphae, flesh beneath the broad somewhat thick-walled cells subgelatinous in KOH and rusty yellow in KOH; clamp connections present.

Habit, habitat, and distribution.—Densely cespitose on oak stumps during late spring and early summer, near Chelsea, Michigan, June 29, 1940, Smith 15156 TYPE; other collections from Michigan are: Smith 1463, 6417, 7017, 7106. Kauffman made collections from North Carolina and Pennsylvania and had studied a collection of mine from Michigan made July 9, 1929.

Observations.—Singer (1951) comments on an undescribed species resembling *Xeromphalina campanella* but growing on hardwood. It must be the one here named in honor of Professor C. H. Kauffman. It can usually be distinguished from *X. campanella* by the more ferruginous pilei of young stages as well as by the difference in the gill trama and habitat. One must distinguish, however, between freshly developing clusters and clusters which have become arrested in their development. As often happens in *Marasmius candidus*, many more buttons are formed than ever reach maturity, and the colors in these fade, as do those of the mature caps.

Subsection **Orickianae**, subsec. nov. Pigmentum pilei in KOH vinaceo-fuscum; pilocystidia ochracea. Typically cespitose to gregarious and, so far, known only on redwood.

6. *Xeromphalina orickiana* (Smith) Singer

Lilloa, 22: 368. 1951

(Pl. VII)

Omphalia orickiana Smith, Mycologia, 30: 36. 1938.

Pileus 10–25 mm. broad, convex, umbilicate or the margin spreading and the disc depressed, at times becoming broadly funnel-shaped with a wavy or subcrenate margin, surface moist to dry, faintly innately fibrillose under a lens, fibrils more numerous around the disc and scattered near margin, color evenly "dark vinaceous brown," margin incurved at first and at times faintly striatulate; flesh thin, hardly tapering toward margin, "dark vinaceous brown," pliant and cartilaginous, odor and taste not distinctive; lamellae narrow, crowded, short-decurrent, at first "pale grayish vinaceous" becoming darker and near "sorghum-brown" at maturity, edges even; stipe 1–3 (4) cm. long, 1.5–2 mm. thick, apex usually enlarged slightly, base often attenuated, surface tawny tomentose below, minutely pruinose above, concolorous with the pileus or darker, tubular.

Spores 4.5–6 × 2–2.5 (3) μ (4–4.5 × 2 μ in mounts of dried material), subcylindric to narrowly ellipsoid, smooth at maturity, pale blue in Melzer's solution; basidia four-spored, 18–20 × 3–4 μ, hyaline in KOH; pleurocystidia scattered, (24) 30–40 × 8–14 μ, fusoid-ventricose to subcylindric or submucronate, hyaline in KOH, thin-walled, smooth, apices obtuse; cheilocystidia scattered to abundant, similar to pleurocystidia but size more variable, some clavate, some obovate, some fusoid-ventricose, hyaline and smooth; gill trama subparallel to interwoven, dark vinaceous brown revived in KOH (when fresh, vinaceous red in KOH), brown in H_2O mounts of fresh material, pileus trama colored like gill trama in KOH except for the cuticular layer, which is golden brown and not gelatinous, numerous pilocystidia arising from the golden-brown cuticular layer and these 20–50 × 6–12 μ, subcylindric, narrowly clavate, subventricose, or somewhat irregular in shape and with thickened, smooth, golden-brown walls as revived in KOH, pigment incrusted on the prostrate hyphae, the cells immediately beneath the golden-brown layer pallid vinaceous in KOH, radially arranged, and larger in diameter than those of the flesh proper (which are dark vinaceous

brown in KOH), the pigment incrusted on the walls in the gill and pileus trama; clamp connections present.

Habit, habitat, and distribution.—Cespitose to gregarious on redwood logs, Orick, Calif., Dec. 4, 1935, Smith 3762.

Observations.—I overlooked the peculiar pilocystidia in my earlier study as well as the prostrate hyphae which give rise to them. In sections of the pileus revived in KOH the differential color reaction is very striking.

SECTION HEIMIOMYCES (SINGER), COMB. NOV.

7. **Xeromphalina tenuipes** (Schw.), comb. nov.

(Pl. VIII, Fig. 1)

Agaricus tenuipes Schw., Trans. Am. Phil. Soc., II, 4: 147. 1822.
Collybia tenuipes Saccardo, Syll. Fung., 5: 213. 1887.
Marasmius amabilipes Peck, Bot. Gaz., 4: 216. 1879.
Heimiomyces tenuipes Singer, Mycologia, 35: 159. 1943.
Agaricus rhabarbarinus Berk., Journ. Bot. and Kew Misc., 8: 135. 1856.

Pileus (1) 2.5–7 cm. broad, obtuse to convex with incurved margin at first, expanding to nearly plane or broadly umbonate, surface dry and velvety in appearance, becoming subgranulose in age, even or somewhat rugose, orange brown with an olive-ochraceous brown sheen when fresh, frequently "russet" on disc and near "ochraceous tawny" toward the margin, margin translucent-striate only in old, water-soaked specimens; flesh pliant, thickish, watery brown, no odor, taste not recorded; lamellae whitish at first but soon pale yellow, bluntly adnate but developing decurrent lines, close, fairly broad, slightly ventricose in age, edges even; stipe 5–8 cm. long, 3–8 mm. thick, equal to slightly enlarged downward, sometimes with a tapering pseudorhiza, pliant and tough, concolorous with pileus and with a similar velvety-tomentose covering extending to the line of gill attachment, base more conspicuously fulvous-pubescent.

Spores 7–9 × 4.5–5 μ, ellipsoid, smooth, blue in Melzer's solution; basidia 23–28 × 6–7 μ, four-spored; pleurocystidia present but embedded in the hymenium, 23–30 × 5–8 μ, fusoid with subacute apices, some with a slight incrustation around the midportion (revived in KOH); cheilocystidia similar to pleurocystidia but often difficult to demonstrate; gill trama interwoven, hyphae with thick-

ened walls and "glassy"-appearing in KOH, hyaline or nearly so; pileus trama with the body of interwoven hyphae like those of the gill trama, the cuticle a tangled turf of thick-walled, rusty-brown hyphal tips projecting, or semidecumbent, as pilocystidia, these often grouped in fascicles and in shape subcylindric with flexuous walls, clavate, or subfusoid, variable in size and arising from appressed brown-walled filaments, which form a thin layer; clamp connections present.

Habit, habitat, and distribution.—Scattered to subcespitose on hardwood, spring and early summer. Widely distributed and often common. Apparently it is quite abundant in the American tropics.

Observations.—This is the largest species in the genus, and as found in the field appears rather variable because the fruiting bodies are quite persistent and undergo considerable change in color in the process of weathering. There is considerable similarity to *Flammulina velutipes* in general appearance, but fresh specimens can at once be distinguished by the contrast of velvety and viscid pilei. In herbarium specimens the reaction of the spores in iodine (Melzer's solution) will distinguish any badly weathered specimens which happen to look alike. Some may wonder why so much emphasis is put on the iodine reaction of the spores here, whereas in such genera as Cystoderma the character is not given equal recognition. In Cystoderma, however, one finds species with amyloid and nonamyloid spores so similar in other characters as not to be easily distinguished, whereas in Xeromphalina there is no such closely parallel series. In addition, to include species with both types of spores in Xeromphalina would remove the one character by which these fungi can easily be excluded from the huge Marasmius complex.

8. **Xeromphalina fulvipes** (Murr.), comb. nov.

(Pl. VIII, Fig. 2)

Gymnopus fulvipes Murrill, North Am. Flora, 9: 369. 1916.
Collybia fulvipes Murrill, Mycologia, 8: 219. 1916.
Heimiomyces fulvipes Singer, Lilloa, 22: 370. 1951.

Pileus 1–2.5 (5) cm. broad, convex to plane, the margin incurved at first and often remaining decurved, surface "Sudan brown" (bright yellow brown) on the disc, "ochraceous tawny" on margin,

smooth, glabrous and moist, faintly striatulate, at times "ochraceous orange" to "zinc-orange," fading very slowly; flesh concolorous with surface, pliant and tough (consistency rubbery), reviving when moistened, no odor, taste bitterish; lamellae close (appearing distant only in broadly expanded pileus), 24–30 reach the stipe, adnate, narrow to moderately broad, 3 tiers of lamellulae, "warm buff" or more brownish (whitish only when very young), edges even; stipe 2–8 cm. long, 1–2.5 mm. thick, equal, tough, stuffed with tawny fibrils, ferruginous to blackish brown and covered over its entire length with "zinc-orange" tomentum, base tawny strigose and often deeply buried in the debris, extreme apex yellowish and pruinose pubescent.

Spores 4.5–6 × 1.7–2 μ, cylindric or in side view slightly curved, smooth, pale bluish in iodine (Melzer's solution); basidia four-spored, 18–24 × 4–5 μ, apices bluish in Melzer's solution (use oil immersion); pleurocystidia rare to abundant, 20–32 × 3–9 μ, fusoid-ventricose at first, soon elongating greatly and with a flexuous hairlike prolongation projecting from hymenium, thin-walled, hyaline in KOH; cheilocystidia similar to pleurocystidia; gill trama of interwoven thick-walled subgelatinous (in KOH) brown to pallid hyphae (with "glassy" appearance in KOH under the microscope); pileus trama with a surface pellicle of subgelatinous hyphae about 2 μ in diam., but this layer easily obliterated and often not demonstrable, beneath it a hypoderm of enlarged yellow-brown cells, the remainder of compactly interwoven hyphae similar to those of the gill trama; clamp connections present.

Habit, habitat, and distribution.—Single to scattered on debris of conifers, more rarely on alder; spring and fall, Washington and Oregon; rare.

Observations.—The thin pellicle is not always to be demonstrated on herbarium material. Apparently it is very easily removed in sectioning the dried material. As a result, the hypoderm is exposed and is then likely to be interpreted as an epicutis. The elements of the hypoderm, in shape and arrangement, resemble those of the cuticle of Psathyrella, but are thick-walled instead of thin-walled, and hence give the surface a cartilaginous feel.

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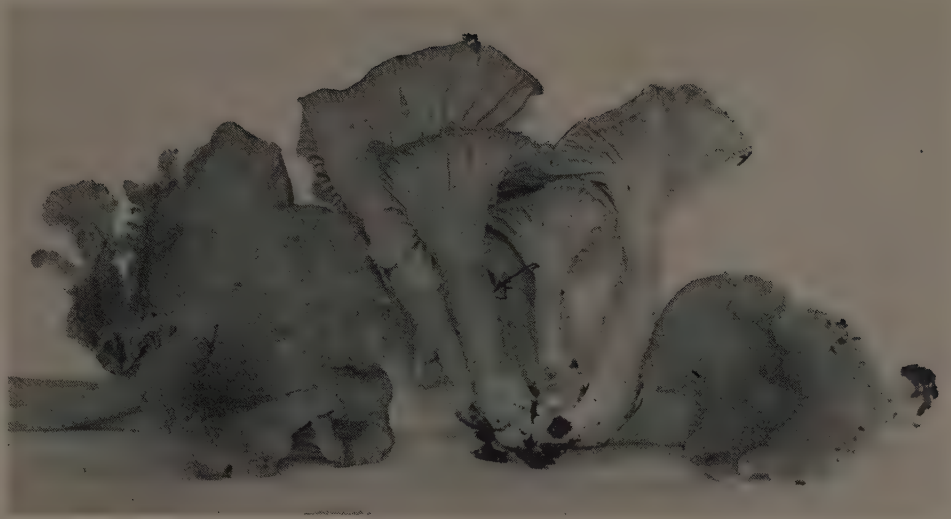
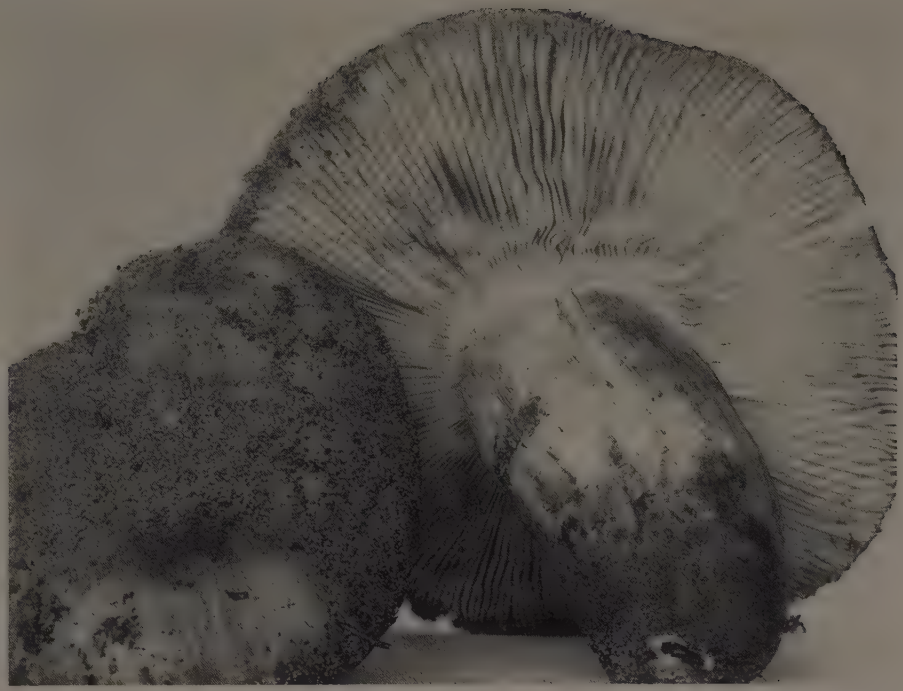
PLATES I–VIII

Cantharellus cinereus f. *multiplex* Smith. × 1



Cantharellus lutescens Fries. × 1

Phaeocollybia Jenniae (Karst.) Romagnesi. × 1



Russula ventricosipes Peck. × 1

FIG. 1. *Xeromphalina cauticinalis* (Fr.) Kühner & Maire. × 1

FIG. 2. *Xeromphalina Kauffmanii* Smith. × 1

Xeromphalina campanella (Fr.) Kühner & Maire. × 1

Xeromphalina orickiana (Smith) Singer. × 1

FIG. 1. *Xeromphalina tenuipes* (Schw.) Smith. × 1

FIG. 2. *Xeromphalina fulvipes* (Murr.) Smith. × 1

THE RESULTS OF HYBRIDIZATION BETWEEN *OENOTHERA ELATA* AND CERTAIN SOUTH AMERICAN EUOENOTHERAS*

ERICH STEINER

Introduction

OF THE considerable number of plants in which circles of chromosomes occur at meiosis, Oenothera is perhaps the best example. Most oenotheras occurring in the midwestern and eastern United States are small-flowered, self-pollinated forms having all of their fourteen chromosomes arranged in a single circle during the meiotic division. Circle formation at meiosis was first shown by Belling (1927) to result from segmental interchange between non-homologous chromosomes. Thus in a form of Euoenothera bearing a circle of fourteen, each of the two genomes or "complexes," which are composed of seven chromosomes, has a completely different arrangement of its fourteen pairing ends. Because these complexes carry balanced lethals which prevent their survival in the homozygous condition, the progeny of such self-pollinated races continue to be translocation heterozygotes with ⊙ 14 at meiosis.[1]

When such races are outcrossed, however, the hybrids may show a meiotic configuration ranging from seven pairs of chromosomes to ⊙ 14. If, for example, two complexes have identical arrangements of pairing ends, the configuration at meiosis will be seven pairs, or, if two of the seven kinds of chromosomes differ in end arrangement, ⊙ 4, five pairs will result, and so forth. The configuration obtained at meiosis when different complexes are combined in hybrids is therefore an index of their similarity in end arrangement. Further, similarity in segmental arrangement can be taken as an

* This study is based on a doctoral thesis submitted to Indiana University in June, 1950. I am indebted to Dr. R. E. Cleland, of Indiana University, for guidance and encouragement throughout the investigation.

Those oenotheras which have been used for most of the genetical studies belong to the subgenus Euoenothera (formerly called Onagra).

[1] For a detailed review of Oenothera cytogenetics, see Cleland (1936).

index of phylogenetic relationship, since, in general, one can safely assume that complexes identical or similar in end arrangement are more recently derived from a common ancestor than those whose segmental arrangements are completely different.

In order to determine which chromosomes differ in end arrangement from one complex to another, a system was devised in which a specific complex was assigned the standard arrangement, 1·2 3·4 5·6 7·8 9·10 11·12 13·14;[2] the segmental arrangement of all other complexes could then be established in terms of this standard arrangement by determining the meiotic configurations of an unknown complex when combined in a series of hybrids with complexes whose segmental arrangements had been worked out (Cleland and Blakeslee, 1930, 1931). With this technique Cleland and his students have been able to determine the segmental arrangement of a large number of different complexes occurring in races of Euoenothera throughout North America. This information, along with genetic analysis and distributional studies, has been utilized in the reconstruction of the phylogeny of the group.

As one facet of the Oenothera studies Hagen (1950) attempted to analyze certain races of Euoenothera from South America in terms of the North American system of end arrangements; thus some indication of the relationships of the North and the South American forms might be obtained. Two difficulties prevented the attainment of this objective. First, the North and South American euoenotheras cross with difficulty, so that the number of hybrids obtained was small; of those which were obtained, many failed at some stage of development before producing the buds necessary for cytological analysis. Second, even if cytological material was obtained from a hybrid, the chromosomes often failed to retain their end-to-end associations and, therefore, the configurations usually failed to remain intact. Although it was possible to identify a few chromosomes of the South American euoenotheras in terms of the North American system of end arrangements, an analysis in which each South American complex is identified in terms of the North American system was not possible.

Although he was unable to relate the South American strains with those of North America, Hagen succeeded in establishing an

[2] Each chromosome is represented by two numbered ends, which are joined by a dot.

independent system of end arrangements within the South American group. A number of South American complexes were either wholly or partially identified in terms of this system.

Since the gap between the North and the South American forms proved too wide to allow cytological analysis of the hybrids between them, it was thought that strains growing in the Central Ameri-

TABLE I

RACES USED FOR HYBRIDIZATION

Race	Species	Chromosome configuration
Chihuata 1	*Oe. campylocalyx*	7 pairs
Cusipata	*Oe. campylocalyx*	⊙ 14
Cuzco 1	*Oe. campylocalyx*	Undetermined
Cuzco 2	*Oe. campylocalyx*	⊙ 14
La Paz	*Oe. campylocalyx*	⊙ 14
Las Lenguas	*Oe. campylocalyx*	7 pairs
Macchu Picchu	*Oe. campylocalyx*	⊙ 14
Ollantaytambo	*Oe. campylocalyx*	7 pairs
Pacar Pass	*Oe. campylocalyx*	⊙ 14
Rio Cochuna	*Oe. campylocalyx*	7 pairs
Villa Nougues	*Oe. elongata*	7 pairs
Rio Chile 1	*Oe. rubida*	⊙ 14
San Lazarro	*Oe. rubida*	⊙ 14
Guatemala	*Oe. elata*	7 pairs

can area might be capable of crossing with both North and South American races and thus act as bridging forms, bringing both groups into a single system of segmental arrangement. Such a form became available through the courtesy of Dr. Paul Weatherwax, who made collections in Guatemala City and Chichicastenango; this race has been named *Guatemala*. The analysis of *Guatemala* in terms of the North American system has been published in a previous paper (Steiner, 1951). The present paper is a report of the results of hybridization of *Guatemala* with the South American races in our collection.

MATERIALS AND METHODS

The races used in this study (Table I) were obtained through the courtesy of Dr. R. E. Cleland. The South American races are dis-

cussed in detail by Hagen (1950). *Guatemala* was hybridized with the South American forms. The various classes of hybrids were identified phenotypically and their chromosome configurations determined. A more extensive presentation of the methods employed is available in the recent collection of papers edited by Dr. Cleland (1950).

Results

The results of hybridizations of *Guatemala* and certain South American races are presented in Table II. In many plants repeated pollinations were necessary to obtain sufficient seed set. Difficulties in getting enough seed may have been related to the lack of vigor and poor vegetative development shown by the South American races when grown under summer field conditions in Indiana. Most of the races are native to more or less alpine habitats, which may partially explain their poor response to the hot summer weather of the midwestern United States.

The wide variation in germination percentages among seeds of different hybrids is shown in Table II. Crosses in which *Guatemala* was used as the male parent were in general more successful than those in which *Guatemala* served as the female parent. Certain crosses produced progeny which exhibited structural and developmental abnormalities or failed to survive (see also Table II). For the most part, those hybrids which survived showed a marked heterosis; they were far more vigorous than the South American races grown under garden conditions. The hybrids were highly sterile; they continued to bloom throughout the summer without setting seed. Among the progeny resulting from the cross *Guatemala* × *San Lazarro* a haploid plant was found; it had the characters of *Guatemala*, although it was smaller and less vigorous.

All the *Guatemala*–South American hybrids showed a strong tendency toward shattering of the chromosome configurations. Much cytological material of each hybrid was examined, but of the fifteen hybrids from which bud material was available eleven did not have chromosome configurations which remained sufficiently intact to be determined. In four of the hybrids a few cells were found with complete configurations, from which determinations were obtained. Three of these (*hGuatemala · a Cusipata*, *hGuatemala · a Cuzco 2*, and *hGuatemala · a* or *b* (?) *San Lazarro*) exhibited ⊙ 14, thus show-

TABLE II

CROSSES OF GUATEMALA WITH SOUTH AMERICAN RACES

A. Unsuccessful pollinations

Pacar Pass × Guatemala	No seed
Rio Cochuna × Guatemala	No seed
Guatemala × Las Lenguas	Empty seed coats

B. Crosses which yielded seed that was not sown*

Cusipata × Guatemala	San Lazarro × Guatemala
Cuzco 1 × Guatemala	Villa Nougues × Guatemala
Rio Chile 1 × Guatemala	Guatemala × Ollantaytambo

C. Crosses which produced hybrid plants

Cross	*Germination percentage*	*Structural and developmental abnormalities and failures*
Guatemala × Chihuata 1	50	Malformation of early leaves; 25 per cent of plants
Guatemala × Cusipata	62	Malformation of early leaves; 80 per cent of plants
Guatemala × Cuzco 2	42	....
Guatemala × La Paz	6	....
Guatemala × Macchu Picchu	16	56 per cent of plants died; remainder chlorotic
Guatemala × Pacar Pass	13	All died
Guatemala × Rio Chile 1	0.9	Died (1 plant)
Guatemala × Rio Cochuna	8	One plant survived in field
Guatemala × San Lazarro	47	44 per cent died; remainder chlorotic; one plant a haploid, *bGuatemala*
Guatemala × Villa Nougues	55	Malformation of early leaves
Cuzco 2 × Guatemala	72	....
La Paz × Guatemala	90	....
Las Lenguas × Guatemala	96	....
Macchu Picchu × Guatemala	77	....
Ollantaytambo × Guatemala	81	....
Pacar Pass × Guatemala	100	Only 2 seeds

* Crosses originally made to insure having sufficient seed of certain complex combinations; these have been obtained from reciprocal crosses which were grown.

ing that these complexes are segmentally unrelated to *ʰGuatemala*.[3] The fourth, *ʰGuatemala* · *ʰVilla Nougues* (⊙ 4, ⊙ 4, 3 pairs), indicates that in segmental arrangement *ʰVilla Nougues* is closely related to *ʰGuatemala*, being only two interchanges removed from it. Unfortunately, only two of the *ʰVilla Nougues* chromosomes have been identified in terms of the South American system of end arrangements. Without further data it is impossible, therefore, to work out the segmental arrangement of *ʰGuatemala* in terms of the South American system of end arrangements.

Discussion

The sterility of these hybrids is undoubtedly related to the failure of the chromosome configurations to remain intact throughout meiosis. That the homologous segments are able to undergo pairing is evidenced by the fact that the broken configurations include chains of varying numbers of chromosomes. Occasionally a configuration remains intact. If it had been possible to examine a much greater quantity of cytological material, a determination for all the hybrids might have been possible. The fragmentation of the configurations appears, therefore, to result from the failure of chiasma formation after pairing has occurred. The complexes combined in these hybrids must have numerous genic differences; as a result, certain portions of the chromosomes in the pairing ends are no longer homologous enough to pair and form chiasmata. Pairing is therefore loose. This results in a reduction of chiasma formation to such an extent that chiasma failure of the fourteen pairing ends in any one spore mother cell is so frequent that only rarely is a complete circle of chromosomes formed. In those hybrids in which a meiotic configuration of ⊙ 14 has been established, the phylogenetic divergence of the *ʰGuatemala* and the South American complexes involves not only maximum segmental dissimilarity but also extensive genic differentiation of the chromosomes, as is indicated by the reduced chiasma formation.

On the other hand, the hybrid combination *ʰGuatemala* · *ʰVilla Nougues* exhibits ⊙ 4, ⊙ 4, 3 pairs at meiosis. These complexes must, therefore, be only two interchanges distant and must have

[3] The superscript *h* ("haplo-") indicates that the complex occurs in duplicate in a homozygous race. The letters *a* and *b* designate the opposing complexes of a structural heterozygote (see, further, Hagen, 1950).

three chromosomes with the same segmental arrangement. On the basis of segmental arrangement alone, one would conclude that these complexes are closely related. Caution must be exercised, however, in interpreting this as an absolute index of relationship. Intact configurations were almost as difficult to find in *ʰGuatemala* · *ʰVilla Nougues* as in the other hybrids. Phylogenetic divergence of these two complexes has involved only limited interchange, yet the homologous segments of the chromosomes have undergone considerable genic differentiation. Genetic divergence is thus not always accompanied by segmental interchange among the euoenotheras. It is also true that, once a complex has become modified by the minimum number of interchanges to give ⊙ 14 with a complex from which the new arrangement was derived, further segmental divergence cannot readily be detected cytologically. In the more distantly related groups this type of cytogenetic analysis has its limitations as evidence of phylogenetic relationships. It is also worthy of mention that *Villa Nougues*, which appears to be more closely related to *Guatemala* than the other South American races are, was collected in Tucuman, Argentina, whereas most of the other races in our collection occur in localities much closer to Central America.

The fact that *Guatemala* did not prove to be a form exactly intermediate between the North and the South American euoenotheras does not mean that such forms do not exist. The number of forms in our collection are few, and it is not unlikely that additional material, especially from lower Central America or northern South America, may be used to relate the two groups.

Summary

1. Results of hybridizations of a Central American Euoenothera with a number of South American forms are presented.

2. An attempt to establish the segmental arrangement of *ʰGuatemala* in terms of the South American system of end arrangements was unsuccessful, because, with few exceptions, the chromosome configurations of the hybrids did not remain intact.

3. All the South American complexes show considerable phylogenetic divergence from the *ʰGuatemala* complex. This divergence involves extensive genic differentiation of the chromosomes; in most plants considerable segmental interchange has also occurred.

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THE RELATION OF *DICHOTOMOSIPHON PUSILLUS* TO THE ALGAL GENUS BOODLEOPSIS*

WM. RANDOLPH TAYLOR, AYLTHON B. JOLY,† AND ALBERT J. BERNATOWICZ

WHEN F. S. Collins in 1909 published his "Green Algae of North America," he included under the genus Dichotomosiphon a new species, *D. pusillus*, provisionally associated with *D. tuberosus* (A. Br.) Ernst on the basis of vegetative characters alone (since reproductive structures were unknown for the new plant) and despite the fact that it was a tropical and subtropical marine species, whereas the classical *D. tuberosus* is a temperate-zone and freshwater species. He ascribed the plant to Jamaica and the West Indies generally, citing no type locality but issuing a specimen collected in Jamaica (No. *1587*) in the exsiccata Phycotheca Boreali-Americana and, later, another collected in Bermuda (No. *2023*), where he reported it as common. So far as we are aware, the plant has seldom been reported and has never been figured. Its curious filament structure and taxonomic allocation have attracted attention (Howe, 1918; Feldmann, 1946), but no one has hitherto had an opportunity to investigate it in detail.

The reported frequency of this species in Bermuda prompted the senior author (W. R. T.) to place a study of it high on the list of desirable tasks in planning his work there in 1949. Later, one of his associates (A. J. B.) spent two additional periods there, and a rather thorough study of Dichotomosiphon resulted, although its full developmental history has, perhaps, not even now been satisfactorily worked out. During the laboratory examination of the collections it became apparent that another of us (A. B. J.) had brought excellent specimens of the same or a closely allied species from Brazil, and so we report on all this material together.

* Contribution No. 966 from the Department of Botany, University of Michigan, and No. 177 from the Bermuda Biological Station for Research.

† From the Department of Botany, University of São Paulo (under a fellowship program sponsored by the Rockefeller Foundation).

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So far as Bermuda is concerned, we did not find that the abundance of *Dichotomosiphon pusillus* had been overstated (Collins and Hervey, 1917). The plant is widespread about the shores of the islands and, though it is a characteristic plant of the mangrove communities, it is not strictly limited to them, for it is also to be seen on patches of mud high in the intertidal region, on rocky shores of quiet bays. The Brazilian plant has so far been collected only once. It was found in dense mats nearly covering the pneumatophores of *Avicennia nitida* Jacq., which here, about the Bay of Guaratuba in the state of Paraná (approximately in lat. 25° 53′ S., long. 48° 35′ W.), forms one of the largest mangrove communities in southern Brazil. The algal mats are made up of the interwoven filaments of several genera, chiefly the species of Dichotomosiphon and Cladophoropsis, but also including a small species of Lophosiphonia, *Caloglossa Leprieurii*, and *Sirocoleum Kurzii* (determined by F. Drouet). Associated with the colonies of Dichotomosiphon are luxuriant colonies of *Bostrychia Montagnei*. The mats of Dichotomosiphon in the dense shade of the mangrove trees are easily overlooked even by one searching for algae, for they are so firmly compacted by the deposition of mud and organic material that the whole appears to be a nondescript spongy body.

The plant consists of coenocytic filaments woven into a vaucherioid mat. Cursory examination discloses an abundance of dichotomies, generally associated with constrictions and very reminiscent of the usual figures of *Dichotomosiphon tuberosus*. Upon closer inspection, differences can be seen between the lower and the upper filaments. Those below on the substrate or buried in mud are dichotomously branched but of irregular contour (Pl. II, Fig. 3) and are not usually so deeply green as the upper filaments, colorless filaments being common and filaments apparently devoid of contents not at all unusual. Thickened walls and expanded forks may occur, especially in the Brazilian material, where the coarse strands

(up to 90 μ in diameter) may form triangular expansions at the dichotomies as much as 200 μ wide and have a lamellate wall as much as 14 μ thick. When the walls are not thickened, the filaments quite frequently show irregularly placed septa (Pl. II, Fig. 8). Very slender as well as coarse filaments may be found. In addition to the dichotomous branching, minor lateral branches occasionally appear. Rhizoids are rather inconspicuous and not sharply differentiated; they may arise from filaments of any category (Pl. I, Fig. 6; Pl. II, Fig. 5).

The differentiation between the lower filaments and those exposed to the light is most pronounced in the denser mats. There, the upper segments become shorter and the forks are marked by a sharp constriction at the base of each branch, a feature absent from the lower filaments (Pl. I, Figs. 1–5; Pl. II, Figs. 1–2; Pl. III, Figs. 1–2, 4). Upper-branch diameters in the Bermudian material are about 23–32 μ, while those in the Brazilian are 27–45 μ. Secondary constrictions between the forks are scarce (Pl. I, Figs. 1–5) or common (Pl. I, Fig. 7), even within a single branch system. The arms of a fork are at first typically symmetrical, but often develop unequally (Pl. I, Fig. 7). Trichotomies are frequent, but more multiple branchings seem to consist of two forks with the intervening segment nearly suppressed.

In addition to the constricted, rather regular upper filaments and the unconstricted irregular lower filaments, the Bermudian material commonly shows a third type of branch, which may be very significant. Usually appearing near the base of an erect system, though sometimes higher (Pl. I, Fig. 7), are short branches which fork irregularly and which lack constrictions more or less completely. These may fork rather loosely (Pl. I, Fig. 8) or so closely as to produce almost coralloid masses, which are hard to dissect and display without breaking (Pl. I, Figs. 9–12).

We took every opportunity, of course, to search for reproductive structures in *Dichotomosiphon pusillus*. That it spreads by means of its creeping filaments and by fragmentation are safe assumptions. Beyond this we still have no complete demonstration of a reproductive process, but we do offer some suggestions as to what we think may occur.

In the Brazilian material one of us (A. B. J.) found potential reproductive structures (Pl. III, Figs. 6–10) which prompted re-

examination of Bermudian samples, where we also found them, though less abundantly. We have since seen them on material from Puerto Rico and the Bahamas that had been collected by M. A. Howe and is now in the Herbarium of the New York Botanical Garden. On the basal unconstricted filaments short side branches arise which terminate in oval or subspherical densely green heads resembling sporangia, and here referred to by that name for convenience. There is, as yet, no proof that they are sporangial in function. On the other hand, they do not resemble the vacuolate filament swellings caused by animal infection that are found in Vaucheria. The diameter of the sporangia in the small group of Brazilian specimens varies from 64 to 153 μ and the length from 83 to 207 μ, so that they average 102 μ in width and 137 μ in length. Careful dissection proved the relationship of these structures to the green vegetative filaments of the plant, for the sporangium shown on Plate III, Figure 6, was attached to the intact, carefully isolated filament system from which Figures 1–3 were drawn, although at a considerable distance (5–6 mm.) from the tips. The walls of these sporangia are sometimes a little thicker than those of the green filaments. In no case was there any associated constriction or septum at the base.

The sporangia found in Bermudian samples were similar to the Brazilian in position and shape (Pl. II, Figs. 5–7). They were smaller, with a width of 60–113 μ and a length of 69–140 μ, the average size being 91 $\times$ 101 μ, but again the number measured was small. We did not succeed in dissecting out complete to the normal green tips individual Bermudian filaments with sporangia. On Plate II, Figures 4–5, however, we show a sporangium with, behind it, the coralloid filament cluster to which it was visibly attached six forks later, at a distance of about 3 mm. There was another sporangium nearby on the same system, two forks distant.

In freshwater cultures, one of which was maintained about eleven weeks, a very remarkable phenomenon occurs. With an increase in the number of cross walls in the basal filaments there is a great change in the upper parts of the filaments. They show reduced and often unilateral branching, with no constrictions, which gives a cervicorn aspect (Pl. II, Figs. 9–11). The contents are dense, although the chromatophores retain their parietal position. The wall increases from the normal thickness of about 1.5 μ to as much

as 3.5 μ. At least in the lower parts of the filament system, where walls are frequent, unmodified portions alternate with the indurated ones, which may lie in the axis (Pl. II, Figs. 13–14) or constitute lateral branchlets (Pl. II, Fig. 12). Thick-walled sections are found in the filament mass (Pl. II, Figs. 15–18), and it seems highly probable that they can act as akinetes, although we did not have time to carry out appropriate culture experiments to verify this.

If one compares our plant with the illustrations in the comprehensive paper by Ernst (1902), where a great variety of growth stages of *Dichotomosiphon tuberosus* are represented, the vegetative similarities are impressive. On the other hand, the irregular tuberiform akinetes which he reports for *D. tuberosus* are different from the rounder bodies that we have tentatively called sporangia in our material. The stalks are longer, and often moniliform, whereas in our plants they are short and smooth. Moreover, several other characters of our plant suggest that it really belongs in a different family of the Siphonales, i.e., the Codiaceae, broadly defined.

In his first description of the genus Dichotomosiphon, based on the freshwater species, Ernst (1902, p. 138) was unable to refer it to any of the described families of Siphonales because he could not reconcile the striking similarity to structural characters of the Codiaceae with the type of sexual reproduction, which resembled that of the Vaucheriaceae. He had at that time in hand a study of developmental stages of Udotea which led him, in a later paper (1904, p. 228), to include Dichotomosiphon tentatively in his subfamily Udoteae of the Codiaceae despite its anomalous sexuality, rather than to associate it with Vaucheria. Remarkable as are some of the structural resemblances of *D. tuberosus* to details found in certain codiaceous plants, we are not inclined to question the independent position of that species. Rather, we are concerned with the greater range of similarities shown by *D. pusillus*.

Ernst's illustrations (1904) show similarities to *Dichotomosiphon pusillus* not only in young stages of his *Udotea minima*, but also in the free filaments produced from damaged blades of *U. Desfontainii* Decne. (*U. petiolata* (Turra) Børg.). On his plate 7 are various similar free green filament systems from both *U. minima* and regenerating *U. Desfontainii*. On his plate 8, illustrating *U. minima*, figure 31 shows the basal part with the differentiation we find among the basal filaments of our plant, figure 22 exhibits secondary con-

striction of a filament, and figure 30 shows the irregular unconstricted type of filament which foreshadows stipe cortication in his plant just as does the production of coralloid filament clusters (Pl. I, Figs. 8–11) in ours.

Ernst was not the first to see and analyze carefully a plant with resemblances to ours. Woronin (1862, p. 208), discussing miniature *Espera mediterranea* Decne., figures (*ibid.*, pl. 10, fig. 1, and pl. 11, figs. 1–2) green vegetative filaments and clustered branchlets quite like those of *Dichotomosiphon pusillus*, and even shows the production of cross walls (*ibid.*, pl. 11, fig. 7), though we have nothing resembling the bodies he figures as possible reproductive organs (*ibid.*, pl. 11, figs. 5–6), nor the calcification he reports. Ernst suggests (1904, p. 230) that these organs were of animal origin, probably being insect eggs. Woronin states (p. 209) that Espera forms great expanses on muddy bottoms near Antibes, the parts beneath the surface of the mud being colorless and provided with numerous fine rhizoids. Because he was able to find in almost every tuft of Espera all the stages intermediate between Espera and Penicillus, Woronin concluded that the former was only a developmental stage of the latter. Hamel (1931, p. 403) gives the nomenclatural history.

Although the presence of intermediate stages, as between Espera and Penicillus, is a very convincing reason for the allocation of such developmental stages to the Codiaceae, the absence of intermediates in a plant does not necessarily exclude a similar assignment. An example of this point of view is seen in Børgesen's (1925) disposition of the plant figured as *Bryopsis furcellata* by Kützing (1856, vol. 6, pl. 71, fig. 2). Kützing's figure of dichotomous, unconstricted, siphonaceous filaments, with no indication of the nature of the basal parts, gives little suggestion of codiaceous affinities. However, at Corsica and in the Canary Islands Børgesen found what he considered to be the same species, and noted that the basal filaments were "torulose or moniliform, irregularly swollen and constricted." Constrictions above the dichotomies were confined almost wholly to the basal branches, although an occasional constriction was present in the upper filaments of the Corsican material. In these and other characteristics Børgesen saw sufficient resemblances to Chlorodesmis and *Udotea minima* to justify placing the plant in the Codiaceae, although the differences prompted him to erect a

new genus, Pseudochlorodesmis, for the species (1925, p. 77). We have no doubt that Børgesen's plant is distinct from ours, for it is much coarser and taller, and differs especially in being constricted only at the basal dichotomies, whereas in our plant the constriction usual at the base of each branch of the upper filaments is absent from the lower filaments. Nevertheless, we feel that his interpretation of the codiaceous nature of Pseudochlorodesmis is eminently reasonable and is equally applicable to our plant.

We remarked above on the development by *Udotea Desfontainii* of free filaments instead of a blade after injury, and it remains to call attention to the spontaneous unconsolidated development of the major part of a frond by Avrainvillea found at Bikini (Taylor, 1950, p. 69). Herein, we think, lies the explanation of certain anomalous collections of Avrainvillea from Bermuda. These were particularly lush filamentous growths which formed loose wefts 3–5 cm. long in sheltered locations in Harrington Sound and Walsingham Pond. The diameters of these filaments ranged from 68 to 100 μ, quite beyond the diameters in the mosslike Dichotomosiphon colonies, and the segments were exceedingly long. At first, the details seemed to resemble Dichotomosiphon in other respects, but the forks commonly showed a notch in the end of the supporting cell between the branches (Pl. III, Figs. 11–12), though it was sometimes obscure (Pl. III, Fig. 13). This is similar to, or identical with, the condition which has been described as having the constrictions above, rather than at, the forks. Branching was much more commonly triple, quadruple, or even quintuple, the branch bases tending to spread in a plane. In much of this material absolutely no organization into stipe or blade occurred, and it is not surprising that we, like Howe before us (New York Botanical Garden Herbarium No. *3962*, from the Bahamas) made the mistake of considering these growths to belong to Dichotomosiphon.

Unless they are comparable to the akinetes of *Dichotomosiphon tuberosus*, the sporangia of our collections have their nearest parallel in the sporangia of Avrainvillea reported by Howe (1907, p. 504), although ours are much smaller than his and show no internal subdivision such as he noted.

In short, then, *Dichotomosiphon pusillus* has much in common with unorganized or juvenile phases of Penicillus, Udotea, and Avrainvillea, and thus supports Ernst's early allocation (1904) of

his genus to the Udoteae better than does *D. tuberosus*. Feldmann (1946), who had studied *D. pusillus* at Guadeloupe, where he found it as a member of the mangrove vegetation (Feldmann and Lami, 1936), considered the presence of two types of plastids (*hétéroplastie*) to point to a similar conclusion, though he maintained the genus in a family of its own.

We now turn to a plant described as *Boodleopsis siphonacea* by A. and E. S. Gepp in their Siboga report (1911). This is a cushion-forming species in every way generically similar to our plant. Their figure 147 indeed seems different in that the main axis appears to be alternately branched, but the more detailed figure 150 corrects this impression. In their figure 151 the notching below a multiple fork is more like what we found in the unconsolidated species of Avrainvillea than like what occurs in *Dichotomosiphon pusillus*. The Gepps apparently saw neither sporangia nor akinete structures.

There is also no little similarity to our plant in the *Rhipidodesmis caespitosa* of A. and E. S. Gepp (1911). Again, their habit drawing (fig. 141) is misleading compared to the detailed drawing (fig. 142). We have nothing just like the densely filled, swollen branchlet segments shown in their figure 143, but, unless these are significant, there seems little of generic value to separate Rhipidodesmis from Boodleopsis. The Gepps stress that the rhizome-like basal part present in their Boodleopsis specimens is absent from Rhipidodesmis. The gradation from thick-walled, horizontal, dichotomous filaments to thin-walled, erect filaments is gradual in young portions of the plants, as shown by our Dichotomosiphon specimens, so that the falsely rhizomatous habit is not evident. The transition is much more abrupt in old plants. The Gepps accept (p. 46, as *Flabellaria minima*) Ernst's account (1904) of a dimorphic condition for *Udotea minima*, but are not alert to the possibility that their two new genera may likewise be growth phases of other plants.

We have a dimorphic state demonstrated for certain species of Penicillus and Udotea. Furthermore, we have plants of similar filamentous types from various stations in areas where Udotea, Penicillus, and Avrainvillea are found which may bear the same relation to as yet undesignated Codiaceae. This association is not known to exist in southern Brazil. Obviously, the genus Dichotomosiphon is not the place for the species *D. pusillus*, which is

related to these secondary states of codiaceous plants rather than to the freshwater *D. tuberosus*. It is so like Boodleopsis that we need not hesitate to place it in that genus: **Boodleopsis pusilla** (Collins), comb. nov., for *Dichotomosiphon pusillus* Collins (1909, p. 431). Even though the possibility exists that *B. pusilla* and *B. siphonacea* may be alternate states of unrecognized larger plants, the genus will serve as a "form genus" until those "species" which are secondary states of more elaborate plants are definitely connected with the fully developed or primary state.[1] M. A. Howe came to the same decision years ago, and annotated accordingly several specimens in the Herbarium of the New York Botanical Garden; he left in an unpublished manuscript an explanation of the need for the transfer, giving reasons which support those detailed above. For the use of this material we are greatly indebted to Dr. D. P. Rogers, Curator at the New York Botanical Garden.

We must withhold judgment for the present respecting Rhipidodesmis because of the sporangium-like filament tips, but its relationship to Boodleopsis or to some other member of the Codiaceae seems very close. Indeed, if dimorphism is found to be widespread in codiaceous plants, it will be necessary to examine critically other genera with more or less unconsolidated filaments, such as Chlorodesmis and Pseudochlorodesmis, to determine whether any of their species are such alternate states.

Distribution.[2]—Bermuda: St. David's I., St. David's Head, terrestrial in a cave, Bernatowicz, No. *50–339*, 1 Dec. 1950 (M); *ibid.*, Great Bay, on a stone jetty, Bernatowicz, No. *50–457*, 18 Dec. 1950 (M); St. George's I., Mullet Bay, on mud among Salicornia plants, Bernatowicz, No. *50–121*, 12 Nov. 1950 (M); *ibid.*, Mangrove Cove, just east of the Biological Station, under Rhizophora, Bernatowicz, No. *51–630*, 8 Jan. 1951 (M); *ibid.*, Lovers' Lake, on mud with *Bostrychia Montagnei*, Bernatowicz, No. *49–104*, 1 March 1949 (M);

[1] The senior author has reëxamined preserved material of his *Derbesia*(?) *fastigiata* (1928) from Florida. It shows many similarities to Boodleopsis species, although lacking constrictions and differing in other details from *B. pusilla*, so that it will need careful restudy, from fresh material, in the light of the suggestions made in the present paper.

[2] The abbreviations used for the various herbaria are: M, Herbarium of the University of Michigan; NY, Herbarium of the New York Botanical Garden; T, Herbarium of Wm. Randolph Taylor.

ibid., Lovers' Lake, on mud and Avicennia pneumatophores, high in the intertidal zone, Bernatowicz, No. *49–1780*, 18 May 1949 (M), and low in the intertidal zone, No. *49–1781*, 18 May 1949 (M); Hamilton I., Tucker's Town Bay, on rocks near high tide, Taylor and Bernatowicz, No. *49–965*, 25 April 1949 (M); *ibid.*, Flatts Inlet, on patches of mud on rocks, Taylor and Bernatowicz, No. *49–185*, 9 March 1949 (M); *ibid.*, near Wistowe, on sand-covered rocks, Collins, No. *7253*, 4 May 1912 (NY); *ibid.*, Shelly Bay, on sand-covered rocks, Collins, Phyc. Bor.-Amer. No. *2023*, 4 May 1912 (M, NY [3 specimens], T). Bahamas: New Providence I., high littoral under shelving rocks, Howe, No. *3061*, 8 April 1904 (NY). Cuba: Prov. Pinar del Río, Puerto Esperanza, on the muddy bottom of a shallow bay, E. Y. Dawson, No. *7573*, 10 May 1949 (M, Univ. So. Cal.). Jamaica: in shallow water, on *Bostrychia tenella*, Pease and Butler, Phyc. Bor.-Amer. No. *1587*, no date (NY, T). Puerto Rico: Salinas Cove, on roots of Rhizophora, Howe, No. *7207*, 27 June 1915 (NY). Brazil: Paraná, Bay of Guaratuba, on Avicenna pneumatophores, Joly, No. *540*, 12 Feb. 1951 (M, Univ. São Paulo, T).

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EXPLANATION OF PLATE I

Boodleopsis from Bermuda

FIGS. 1–5. Typical terminal branching, chiefly dichotomous, with marked constrictions at the base of each branch. × 130

FIG. 6. Irregular terminal branching, with one ramulus becoming rhizoid-like. × 130

FIG. 7. A somewhat irregular system of branching. The typical dichotomous branching shows at the top, but it is modified below by extensive secondary constriction between the forkings, and at "A" a coralloid mass of closely forked branches appears. × 130

FIG. 8. A portion of a branch system with slightly irregular unconstricted divisions. × 130

FIGS. 9–12. Small portions from coralloid masses with irregular, chiefly unconstricted, branching. × 130

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EXPLANATION OF PLATE II

Boodleopsis from Bermuda

FIGS. 1–3. Three portions of a single branch system, showing, in Figure 1, the upper terminal dichotomous and constricted portion, in Figure 2, a portion which is irregularly forked and unconstricted, and in Figure 3, the tip of a basal branch with thick walls and no constrictions. × 130

FIGS. 4–5. Two portions of a branch system from the basal part of a colony, showing, in Figure 4, a section of a coralloid mass with irregular, chiefly unconstricted branching which is connected by long filaments with the simple forks, rhizoidal branch, and sporangium shown in Figure 5. × 210

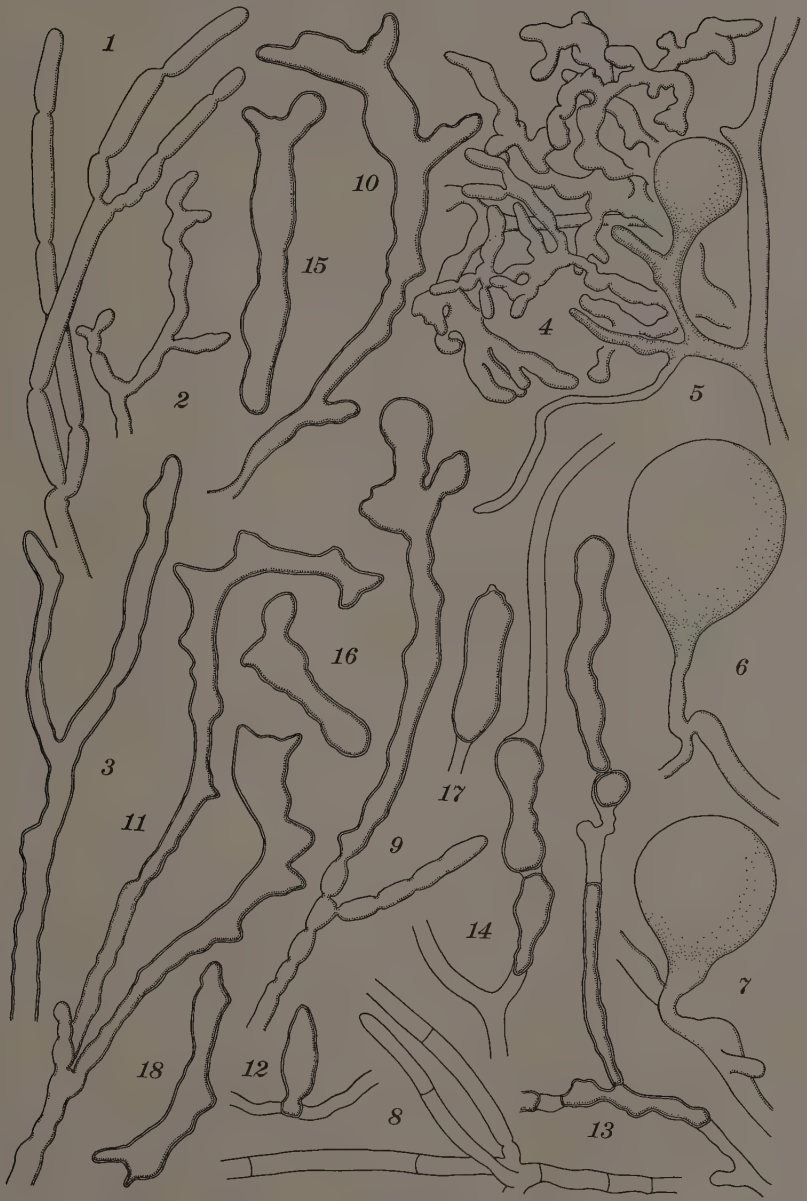
FIGS. 6–7. Two sporangial structures from the basal part of a colony. × 210

FIG. 8. A small portion of a basal branch system showing one constriction but several irregularly placed cross walls. × 130

FIGS. 9–11. Terminal portions of erect branches with dense contents and thick walls. × 130

FIGS. 12–14. Portions of filaments with the dense protoplasm segregated by cross walls into akinete segments. × 130

FIGS. 15–18. Free akinetes from among the filaments of a tuft. × 130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EXPLANATION OF PLATE III

Boodleopsis and Avrainvillea

FIGS. 1–4. Boodleopsis from Brazil. Portions of a single branch system are shown in Figures 1–3, the terminal branching usually being dichotomous (Fig. 1), but sometimes trichotomous (Fig. 2), and constricted, and the basal branching (Fig. 3) being thick-walled and not regularly constricted. Figure 4 shows a closely branched terminal portion from another slide. × 110

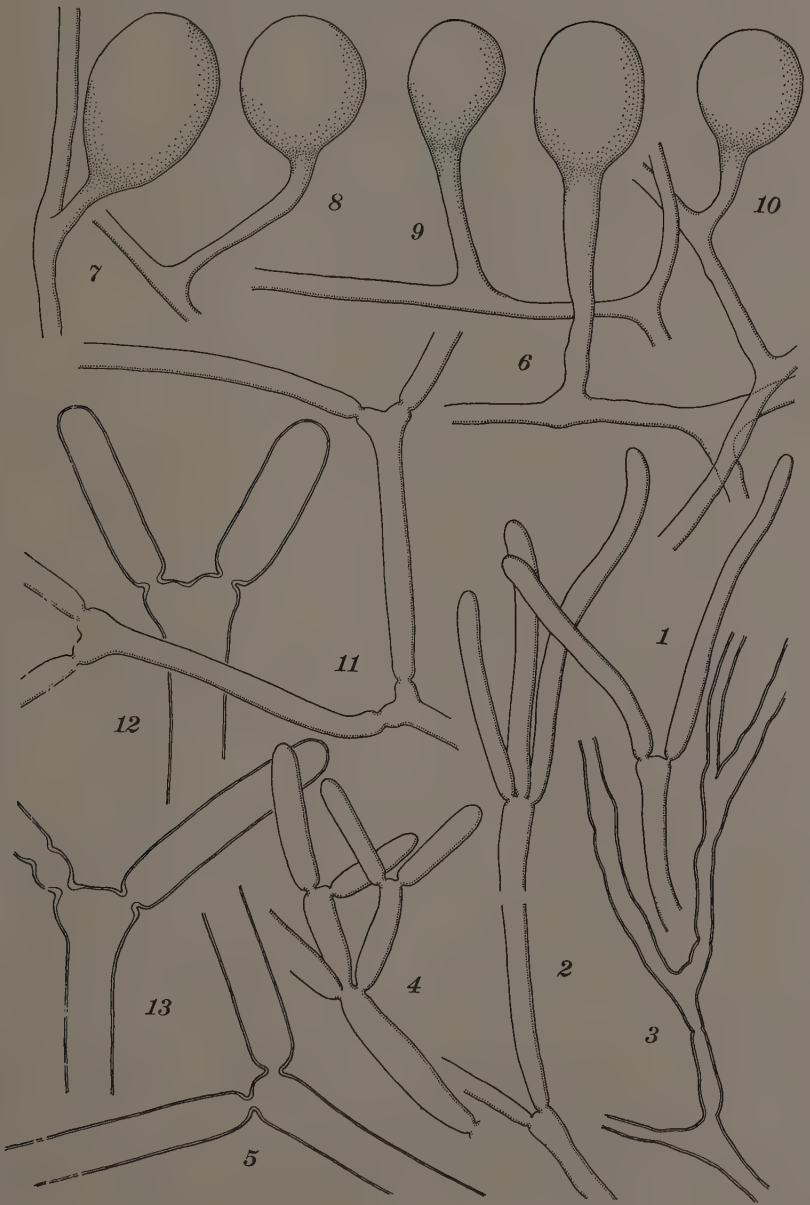
FIG. 5. Boodleopsis from Brazil: detail of a fork showing the wall thickening at the constriction. × 210

FIG. 6. Boodleopsis from Brazil: a sporangium from the basal filament of the same branch system shown in Figures 1–3. × 130

FIGS. 7–10. Boodleopsis from Brazil: other sporangia from the same collection. Figure 7, × 130; Figures 8–10, × 210

FIG. 11. Avrainvillea from Bermuda: a portion of a branch system from a nonflabellate tuft. × 60

FIGS. 12–13. Avrainvillea from Bermuda: terminal portions of branches from a nonflabellate tuft, showing wall thickening at the constrictions. × 130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THE CORRELATION BETWEEN THE NUMBER OF LENTICELS ON POTATO TUBERS AND THE SUSCEPTIBILITY TO THE POTATO-SCAB ORGANISM (*STREPTOMYCES SCABIES* (THAXT.) WAKSMAN AND HENRICI)*

EDWARD F. WOODCOCK

THE lenticels on the tubers of the Irish potato (*Solanum tuberosum* L.) are quite similar in construction to those commonly observed on stems in general. The continuity of intercellular spaces in the lenticel with the outside of the plant would seem to serve as a path for the entrance of disease-producing organisms. Humphrey[1] states that the dark brown spots which are evident on potato tubers infected with the potato-scab organism (*Streptomyces scabies* (Thaxt.) Waksman and Henrici) mark the position of the lenticels in which the disease originates. Since this idea is quite generally accepted among plant pathologists, it was thought advisable to count the lenticels on a certain number of tubers of several potato varieties and compare these numbers with the susceptibility to the potato-scab organism.

The lenticels were counted on one hundred tubers of each of the following varieties: Pontiac, Russet Rural, Sebago, Katahdin, and Chippewa. Only twenty-nine tubers of the Menominee variety were available for counting. The volume and weight of each tuber were determined before the counts were made. Each tuber was brightly illuminated, and the lenticels were located under a binocular microscope. Each lenticel counted was marked with India ink so that no duplication would occur.

An analysis of the results, shown in Table I and Figures 1–2, indicates that even though it has been suggested that the potato-

* Contribution No. 52–14 from the Department of Botany and Plant Pathology, Michigan State College.

[1] J. E. Humphrey, "Report of the Botanist," *Mass. Agric. Exp. Sta. Rep.*, 7: 214–23. 1889.

scab organism enters through the lenticels, the more susceptible varieties have a smaller number of lenticels than the less susceptible

Fig. 1. Comparative frequency of lenticels on potato tubers of six varieties—per cubic centimeter and per gram (broken lines). Only 29 tubers of M were counted; 100 of the others.

Fig. 2. Comparative natural susceptibility to infection by potato scab in six varieties of potatoes. The longest line indicates the greatest susceptibility.

Abbreviations: *C*, Chippewa; *K*, Katahdin; *P*, Pontiac; *R*, Russet Rural; *S*, Sebago; *M*, Menominee

ones. The most susceptible variety, Chippewa, has 4.6 lenticels per gram of tuber tissue and 4.9 lenticels per cubic centimeter of tuber tissue, whereas the less susceptible variety, Sebago, has 6.8

TABLE I

AVERAGE NUMBER OF LENTICELS PER CUBIC CENTIMETER AND PER GRAM ON THE TUBERS OF EACH OF SIX VARIETIES OF POTATOES

	Lenticels per cc.	*Lenticels per gram*
(Menominee	4.0	3.6)
Chippewa	4.9	4.6
Katahdin	5.3	4.9
Pontiac	6.7	6.2
Russet Rural	7.7	7.1
Sebago	7.6	6.8

lenticels per gram of tuber tissue and 7.6 lenticels per cubic centimeter of tuber tissue.

It can be concluded from the data obtained that there is no correlation between the number of lenticels present on a potato tuber and the susceptibility to the potato-scab organism.

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FORESTRY

SOME RESUPINATE POLYPORES FROM THE REGION OF THE GREAT LAKES. XXIV

DOW V. BAXTER

STUDENTS of forest pathology are in reasonable agreement about the main characters of polypores, but there always exist differences of opinion concerning synonymies and the division of certain forms which are often collectively regarded as species. It is believed, however, that interpretations for species widely distributed over North America and other continents can be correctly understood only by studying them comparatively over the entire field and with at least some cultural experiments. Such a procedure leads to rather broad concepts of the species. Knowledge of the type of decay, both incipient and advanced, is also often helpful. Although the advanced stages of decay caused by *Poria Weirii* and *P. albipellucida*, for example, are similar, the incipient rots differ.

This method of study obviously results in concepts embracing growth forms or races, just as does the study of the widely distributed host plants, such as ponderosa pine. It was in the hope of obtaining such an appreciation that I began in 1920 an examination of the material preserved not only in the larger herbaria in the United States and elsewhere in North America, but also in those of Europe. This work has involved many expeditions to Alaska and the Yukon Territory, the Northwest Territories, Labrador, and other Canadian areas, as well as to the various vegetative regions of the United States. The study of the polypores for their geographic range, reactions to different environments, and responses to various substrata merits special attention in the field of forest and forest-products pathology.

This paper continues the series of descriptions of the resupinate polypores begun in 1926. It places emphasis upon geographical distribution, occurrence, and responses of *Poria Weirii* to its various environments. *P. Weirii* Murr., once considered the chief cause of butt rot in standing green *Thuja plicata* and specific to that tree, is here recorded as a fungus that attacks cedar products in certain

environments of southeastern Alaska. It is no longer known as a fungus specific to western red cedar, but the possible existence of races, not now demonstrated, must be recognized.

Poria Weirii Murr., Mycologia, 6: 94. 1914.

Important specimens examined:

Poria Weirii Murr., type, on *Thuja plicata*, Priest River, Idaho. J. R. Weir. Herb. New York Botanical Garden.

Poria Weirii on *Pseudotsuga taxifolia* Buckland. Herb. Division of Botany and Plant Pathology, Ottawa, Canada.

Poria Weirii on *Thuja plicata*, Voight Experimental Forest, U. S. Forest Service, near Outing, Washington. Herb. Dow V. Baxter.

Fructification (see the description presented in paper V of this series [1]).

Allied species.—The light, corky-spongy nature of the brown fruiting body, the large, occasionally encrusted setae, the abundance of setal hyphae, the ellipsoidal spores, measuring 4–5 × 3 μ, and the readiness with which the tube layers can be separated are the most distinctive characters. The laminated rot caused by the fungus is also typical (2).

There are, however, several brown, nonwoody, closely related resupinates that one should consider in making determinations. They are *Poria ferrugineo-fusca* Karst., *P. ferruginosa*, *P. ferrea*, *Trametes isabellina*, and *Fomes nigrolimitatus*.

The spores of *Poria ferrugineo-fusca*, often a somewhat corky perennial, are allantoid and measure 4–5 × 2 μ, but it is to be noted that the ellipsoidal spores of *P. Weirii* are mostly 4–5 × 3 μ. *P. ferrugineo-fusca* and *P. Weirii* resemble each other in many features exhibited in cultures. They are to be distinguished in culture by the somewhat slower rate of growth of *P. ferrugineo-fusca* and by color. The mycelium of *P. Weirii* is uniformly brown or red brown, whereas that of *P. ferrugineo-fusca* exhibits white as well as brown areas of mycelium in culture. This feature is to be noted in one-year-old wood-block cultures and also in petri-dish tests. Furthermore, the mycelium of *P. Weirii*, unlike that of *P. ferrugineo-fusca*, often collapses in older parts of petri-dish tests.

Poria ferruginosa, a fungus that inhabits both conifers and hardwoods, has undoubtedly been mistaken for *P. Weirii* on

occasion. The spores, too, of *P. ferruginosa* are ellipsoidal or subglobular, as are those in *P. Weirii*. The spores of *P. ferruginosa* are 4–5 (4) × (3) 2.5–4 μ. This fungus often attacks the wood of *Thuja occidentalis*. Although a laminated condition frequently results in the decay caused by *P. ferruginosa* in cedar logs, it is a white rot. *P. Weirii* gives a laminated yellow or brown rot. In culture, *P. Weirii* grows more rapidly than does *P. ferruginosa*.

Poria ferrea occurs mostly on hardwoods, but since this brown and sometimes corky resupinate also attacks conifers, it should be compared with *P. Weirii*. The spores will readily serve to separate the two organisms. In *P. ferrea* they measure 5–7 × 2–2.5 μ, whereas in *P. Weirii* they are mostly 4–5 × 3 μ and are ellipsoidal. In rate of growth *P. ferrea* is slow and corresponds to *P. ferruginosa*. Both *P. ferrea* and *P. ferruginosa* grow much more slowly than does *P. Weirii*.

Trametes isabellina, a brown polypore that is often seen in the resupinate condition on coniferous wood, may be separated from *Poria Weirii* by the spores. The spores of *T. isabellina* are 6–9 × 2 μ, whereas those of *P. Weirii* measure 4–5 × 3 μ and are subglobose to ellipsoid. *P. Weirii* grows faster in culture than does *T. isabellina*. See Table I.

Even *Fomes nigrolimitatus* Rom., a common coniferous fungus in parts of the American West, may at times be somewhat corky and might be confused with *Poria Weirii*. The large white pocket rot produced by *F. nigrolimitatus* will at once be evident to the field man if this fungus is encountered. The generally darker color and the black lines which appear in the older parts of the context of the fruiting bodies of *F. nigrolimitatus* will also serve as means of distinction.

Habitat.—*Abies amabilis*,[1] *A. grandis*,[1] *A. lasiocarpa*,[1] *Picea sitchensis*,[1] *Pinus ponderosa*,[1] *Pseudotsuga taxifolia*, *Thuja plicata*, *Tsuga heterophylla*.[1] It has been reported on *Chamaecyparis thyoides*, but the determination has not been verified (8).

Distribution.—Alaska; British Columbia; Idaho, Montana, Oregon, Washington.

Occurrence.—*Poria Weirii* is widely distributed in both coastal and Interior forests of the Pacific Northwest. Important evidence

[1] T. S. Buchanan (4).

presented by Buckland (5), based upon identification of the organism in the field and by cultural methods, shows, however, that past records of abundance, as well as the actual occurrence, of *P. Weirii* are subject to question because two significant fungi may be present that cause similar laminated rots except in the

TABLE I

RATE OF GROWTH IN MILLIMETERS OF PORIA WEIRII AND CLOSELY ALLIED RESUPINATE POLYPORES ON MALT-EXTRACT AGAR IN FOURTEEN-DAY PETRI-DISH TESTS

Fungus and host	25° C.	30° C.	35° C.
Poria Weirii on *Thuja plicata*, U. S. Div. For. Pathol. . .	41	3	0
P. ferrugineo-fusca on *Pseudotsuga taxifolia*, Oregon . . .	36	11.5	0
P. ferrugineo-fusca F 8221 A on *Pseudotsuga taxifolia*, Canadian Forest Products Lab.	37	5	0
Poria culture 9 on *Abies sp.*, Foster, Oregon	1	1	0
P. ferruginosa on *Prunus serotina*, Munising, Michigan	4	0	0
P. ferruginosa on *Acer saccharum*, Michigan	23	0	0
P. ferruginosa on *Thuja occidentalis*, International Falls, Minnesota	25	20	0
P. ferruginosa 33, on *Thuja plicata*, Portland, Oregon . .	15	0	0
P. ferrea on *Acer macrophyllum*, Oregon	15	0	0
P. ferrea on *Alnus sinuata*, Skagway, Alaska	3	0	0
P. ferrea on *Alnus rubra*, Oregon	20	0	0
P. ferrea on *Corylus sp.*, Oregon	15	0	0
P. ferrea on *Salix sp.*, Oregon	30	0	0
Trametes isabellina 6 W on *Picea glauca*, Selkirk, Yukon Terr.	13	12	0
T. isabellina 10 W on *Picea glauca*, Selkirk, Yukon Terr.	12	0	0

incipient stage. His studies show that the major damage in the Interior British Columbia cedar may be attributed to *P. Weirii*, whereas that in the coastal forests is caused by *P. albipellucida* Baxter.

Furthermore, investigations made later in British Columbia (5, 10) and in western Washington and Oregon (3, 4, 6) prove that *Poria Weirii* is not confined to *Thuja plicata*. Intensive surveys carried out in British Columbia have disclosed infection

to be common in twenty-, thirty-, and forty-year-old Douglas fir (9). The pathogen has also been isolated from rot in 100- and 200-year-old Douglas fir and also from western hemlock (*Tsuga heterophylla*). Root rot in Douglas fir caused by *P. Weirii* in the West Coast forests of Washington and Oregon is said to be widely distributed (6), and it is abundant in many localities.

Fire scars and other injuries to the basal parts of the tree are courts for infection, so that *Poria Weirii* is most likely to occur in damaged cedar. Moreover, it has long been known that the fungus fruits abundantly on dead cedar snags and stumps, but it has attracted attention chiefly because of the damage it causes to standing timber.

The record of *Poria Weirii* attacking wood products was made during the field season of 1951 at Old Kaasan, an abandoned Haida Indian village on Skowl Arm, Prince of Wales Island, Alaska (Pl. I). This collection also extends the northern range of the fungus, and it is the first account of the occurrence of *P. Weirii* in Alaska. There it was causing the rapid destruction of old totem poles (Pls. II–III). In this very wet climate (rainfall approximately 160 inches annually) *P. Weirii* was growing in an environment unlike that of Interior sections of either Alaska or British Columbia or Oregon or Washington, where there is considerably less rainfall.

This field record substantiates frequent experiences with cultures in the laboratory involving the growth of resupinate polypores in environments totally unlike those in the forests. If environmental conditions are favorable, it is evident that many of the fungi that cause decay in standing timber will produce rot in wood products. Old Kaasan is the only area in Alaska where *Poria Weirii* is known on a timber product.

Cultures.—Isolated from *Thuja plicata*, U. S. Division Forest Pathology. *Poria Weirii* in culture is distinctive because of its loosely arranged, almost hairlike "honey-yellow"[2] or "buckthorn-brown" mycelium that is woolly in appearance, quite unlike the chamois, leathery, or cottony growth of many of the brown porias. In one-week-old cultures the mycelium is white, with a well-defined margin.

[2] Color terms within quotation marks are those of R. Ridgway, *Color Standards and Color Nomenclature* (Washington, D.C., 1912).

Microscopic features.—The aerial mycelium at first is white, but later becomes buff to brown, thin-walled with numerous cross walls, branched, and measures 3.0–6.0 μ; setal hyphae mostly numerous, tapering to a point, with thick brown walls; they measure 3.0–5.0 μ in diameter (9).

Tannic acid tests.—The fungus gives a positive reaction to tannic acid medium, producing strong diffusion zones.

Growth rate.—*Poria Weirii* grows best at 25° C. Practically no growth takes place in two-week-old malt-agar tests at 30° C., and no development is evident at 35° C. (Table I).

Decay.—In western red cedar the heartwood turns slightly yellowish in the incipient stages. The wood becomes soft and flaky in later stages, and the annual rings separate readily so as to form a laminated rot. The wood becomes pitted and may be filled at first with whitish fibers, but these later appear empty. The summerwood of the annual ring resists attack more readily than the springwood. Soft webs of brown mycelium often grow between the easily separated layers of wood. This "yellow ring rot" is crescent to circular at the log ends. The rot rarely extends the full length of the trunk. Soundings on the trunk and root spurs often reveal the hollowness of the butt parts of the tree (7).

The decay caused by *Poria Weirii* and that resulting from *P. albipellucida* are so similar in gross appearance that the two have been confused, an apparent reason why the rot caused by the latter fungus has been almost unrecognized in the past. Most ring rot of cedar has been attributed to *P. Weirii* (5). Since both fungi cause a white to yellow ring rot of living cedar, a description to differentiate the incipient decay caused by *P. albipellucida* is in order. In rot resulting from *P. albipellucida* a bluish marginal discoloration or the suggestion of darker, reddish stains at the limits of the incipient rot is evident. Later the wood becomes much softened, and the discoloration is more distinct. In the advanced stage the annual rings separate because the early wood decays more quickly than the late wood, and the typical laminated ring rot appears. In this stage the rots caused by the two fungi can be separated, according to Buckland's criteria (5). *P. albipellucida* ring rot commonly shows conspicuous white mycelial flecks between the laminae, and the wood surface has minute elongate fine pits. The late advanced stage is a typical

ring rot, rarely fibrous in nature. On the other hand, the rot produced by *P. Weirii* sometimes shows small patches or a thin web of dark-brown setal hyphae between the laminae, and the wood exhibits long striations or thin, closely packed pockets which, before the complete separation of the laminae, contain white material, probably cellulose products. This striation of the laminae gives the advanced rot a fibrous texture. It is stated (5) that pole-cutting operators in the Interior of British Columbia refer to the *P. Weirii* rot as "paper rot" because the advanced stage is a mass of thin, flexible laminae. On the British Columbia coast this term has not been applied to the rot caused by *P. albipellucida* since the final stage is coarsely laminated or is a crumbly, amorphous mass. Ants and termites are commonly associated with this rot.

The rot *Poria Weirii* causes in Douglas fir does not differ appreciably from that it causes in western red cedar (9). In both species a root and butt rot results that indirectly leads to blowdown (Pl. IV); the affected wood is pitted, and a laminated rot is produced.

The laminated rot due to *Poria albipellucida* Baxter cannot be distinguished from that caused by *P. Weirii* except in the incipient stages or by the brown wefts of mycelium of *P. Weirii* that may be present in wood attacked by *P. Weirii*. In the early stages of the "white" laminated rot arising from infection by *P. albipellucida* the cedar wood commonly exhibits conspicuous white mycelial flecks between the laminae.

Importance.—Loss in wood volume is not necessarily a criterion for damage. However small the actual amount of rot caused by *Poria Weirii* may be, the fungus results in considerable loss of sound material through wind breakage. *P. Weirii* in Interior British Columbia produces a loss of approximately 8 per cent of the cubic volume and 18 per cent of the length of infected timbers.

Because damage it causes to red cedar is so often attributed to wind or insects, the destructive capacity of this fungus has not been generally appreciated (6). If it occurs in standing western red cedar in Washington, Oregon, and Alaska, as it does in British Columbia, it will be more serious in Interior-grown *Thuja plicata.*

The question concerning the further development of a fungus

in a product from a standing infected tree in a forest has long been an important one with pole industries. In general, it has been believed that the organisms causing brown cubical rots of green timber do not continue to develop in the product. The present report of *Poria Weirii* growing on totem poles focuses new attention upon the possibilities of its developing in set poles provided environmental conditions are right for its continued growth.

Trametes serialis, the cause of a brown cubical rot in *Thuja plicata*, has also been found in Alaska attacking totem poles (Pl. V).

The behavior of the fungus on Douglas fir in both British Columbia and the United States is of special concern. It not only causes an appreciable volume loss as a heartwood-decay organism of living trees, but also kills trees of all ages since its activity results in root rot. These two dangers, together with the likelihood of windthrow of weakened trees, make *Poria Weirii* a potentially serious enemy of Douglas fir (5). The fact that this fungus can live in old stumps and reinfect the next generation of trees has serious implications. Since Douglas-fir management is forced to concentrate more and more on second growth (5), potential losses from *P. Weirii* and their possible control should be given consideration.

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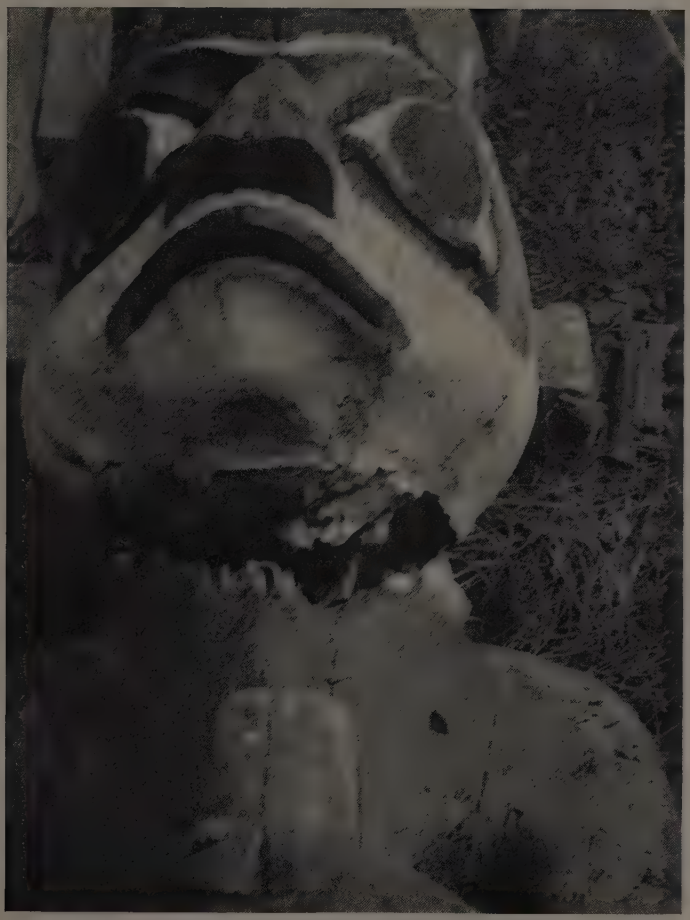
PLATES I–V

Poria Weirii on totem, Old Kaasan village site, Alaska

Decaying western red-cedar totems, Old Kaasan village site, Alaska. Courtesy U. S. Forest Service

Group of decaying Haida totems at Old Kaasan village, Skowl Arm, Alaska. Courtesy U. S. Forest Service

Poria Weirii root rot (abundant fruiting bodies on old, fire-charred cedar) in almost pure stand of second-growth Douglas fir. Windthrown Douglas-fir trees showed no evidence of fruiting bodies. Voight Creek Experimental Forest, near Outing, Washington



Decay in totem caused by *Trametes serialis*

BITTERLICH'S METHOD OF DIRECT BASAL-AREA ESTIMATION

JOHN CAROW

IN THE issue of the *Journal of Forestry* for January 1952 there appeared an article by L. R. Grosenbaugh entitled "Plotless Timber Estimates—New, Fast, Easy" (4) which formally introduced to American forestry the interesting method of an Austrian named Bitterlich for estimating the basal area of a stand of trees. First published in 1948 (1), Bitterlich's method has received widespread attention in Europe, and during the last year or two many American foresters have been using the technique and exploring its possibilities. In this paper I wish to review the theory and the application of the method and to report on the experience we have had with it in the School of Natural Resources at the University of Michigan.

In the simplest use of Bitterlich's method the observer takes his stand at one or more points in the forest, corresponding to plot centers, and sights at each of the surrounding trees at d.b.h. through a simple instrument that is set to measure a small horizontal angle called the "critical angle." All trees appearing larger than the front sight, or the crossarm, which measures the critical angle are counted, and the average count from the several occupied points multiplied by a constant "basal-area factor" gives the estimate of basal area of trees per acre.

Theoretical Considerations

The delay in publishing an American interpretation of Bitterlich's method can be partly explained by the paradox that though the technique is extremely easy to apply, its explanation is difficult to phrase. The average forester finds it hard to see how a simple count can become an estimate of basal area per acre that is closely comparable in accuracy to the old, familiar method of measuring tree diameters on plots of definite size and then laboriously looking up component areas in a table. Grosenbaugh's published explanation is reasonably understandable. He likens the tree count from

several sample points to the dot count foresters make in determining mapped type areas with dot-grid overlays. Both are sampling techniques which turn counts into estimates.

Another approach is to consider that each point occupied by the observer is the center of an infinite number of concentric circular plots. The instrument when sighted in turn at each tree surrounding the point tells whether or not it falls within a plot whose area is some constant multiple of the basal area. Suppose we should arbitrarily say that to be counted a tree must fall within a plot whose total area is 4,356 times the tree's basal area. This plot would have a radius 33 times the tree diameter. Then a tree having exactly 1 square foot of basal area would be counted if it fell in a plot of 4,356 square feet or 0.1 acre. If this plot were then converted to acre size, the tree basal area would be multiplied by 10. Again, under the same assumptions of proportionate plot size, a tree 12 inches in diameter would be counted if it fell in a plot with a radius of 33 feet. Here the tree's cross section has 0.7854 square feet, the corresponding plot area is 4,356 $\times$ 0.7854 or 3,421.2 square feet, and the blow-up factor to adjust the figures to an acre is

$$\frac{43{,}560}{3{,}421.2} = 12.732.$$

It is obvious that the tree basal area, 0.7854, multiplied by the blow-up factor, 12.732, again equals 10 square feet because the proportionality of plot size to tree size results in each counted tree contributing the equivalent of 10 square feet of basal area to the acre estimate.

The Bitterlich scheme would be of no practical value if the diameters of the trees and the distances from the point both had to be measured to see if any particular tree was close enough to the point to be counted. Fortunately, however, the ratio of the tree's size to the size of the plot upon which it may be counted can be expressed in the ratio of the tree radius to the plot radius, and this ratio is the sine of a definite angle. Twice this angle is the so-called critical angle. Any tree appearing to intercept an angle greater than the critical angle is counted, and those trees failing to do so are ignored. It is possible to choose from a wide range of plot-size and tree-size proportions, and these will have corresponding basal-area

factors and critical angles. In his article Grosenbaugh presents a table on useful critical angles and basal-area factors.

It is clear that with this angle-measuring technique small trees are counted only when they are close to plot center, while the largest trees may qualify even when far outside the boundaries of fifth-acre or quarter-acre plots. This is reminiscent of common survey technique, which calls for tallying small trees only on concentric subsample areas, such as one fortieth of an acre, whereas larger trees are tallied on quarter acres. Bitterlich's method, however, insures that the tree count is proportional to basal area per acre for all the sizes and does away with boundary measurement. Since small trees are counted only when located near the point of sighting, the objection can be made that the method is more sensitive to patchy distribution of trees than is the method using fixed-area plots. This is, of course, true, and it may be that the compass man in trying to avoid patches of small trees would contribute to biased results. It should be remembered, however, that in the point-count scheme the count from several points should be averaged.

Preliminary tests have shown that the errors which occur in applying the Bitterlich method may be closely associated with the size of the critical angle unless extreme care is exercised in making the counts. Small critical angles tend to yield underestimates of basal area per acre, and large angles may give overestimates. In an earlier article Grosenbaugh (3) reports that in Southern timber a critical angle of 104.18 minutes with the convenient basal-area factor of 10 gave the most accurate basal-area estimates. This was verified for Michigan forests by Albert Stage (6) in unpublished studies made at the School of Natural Resources in 1951. At twenty-four points, in both coniferous and hardwood stands, Stage compared basal-area estimates derived from fixed-radius plots with those obtained by the Bitterlich method with three different critical angles. His results showed that a critical angle of 75 minutes with a basal-area factor of 5.25 yielded estimates by the Bitterlich method which were 15 per cent below those derived from comparably placed fixed-radius plots. On the other hand, a large critical angle of 232 minutes with a basal-area factor of 33.33 yielded an estimate which was 20 per cent above estimates given by the fixed-radius plot. Stage's third test, with critical angle of 104.18 minutes and a basal-area

factor of 10, gave him basal-area estimates by the Bitterlich method that were only 3.5 per cent higher than those obtained by the fixed-radius plot.

Small critical angles call for relatively long sights, and these are subject to visual interference by brush and trees and to a lack of precision in perceiving the edges of trees at some distance from the point, especially on dark days. This fact probably accounts for the underestimates that are associated with the small angle. A British study, reported by Keen (5), used a critical angle of 20 mills, or about 70 minutes, and a basal-area factor of 4.36, but found no consistent bias in comparing basal-area estimates under the Bitterlich scheme with those from fixed-radius plots. However, Keen and a partner worked in pairs and marked each tree, being very careful about those that were doubtful. This extra care may account for their not experiencing the consistent discrepancy found by Stage and Grosenbaugh when using small angles. With a small critical angle there is a partial compensation in the higher tree count, the lower basal-area factor, and the relative elimination of errors due to the clustering of small trees. With a large critical angle, on the other hand, the number of trees counted is small, and a large basal-area factor magnifies counting errors, which probably tend to overestimation. The overestimates associated with a large critical angle may be due to a tendency on the part of the observer to count a tree which is near at hand and seems to qualify, even though it actually does not. Foresters have often observed a tendency to overestimate volumes when they are using very small sample plots.

Critical-Angle Measurement Devices

Grosenbaugh (4) describes two practical optical instruments for sighting trees to determine whether they should be counted. One is a stick 33 inches long with a peep sight at one end and a 1-inch crossarm at the other, so that a 104.18 minute angle is established with a convenient basal-area factor of 10. The other instrument he suggests using is a monocular with a mill-scale in the objective. This would be similar to the familiar Army binocular. Bitterlich (2) evolved an instrument, called a Relascope, which has a plumbing arm coupled with the crossarm, so that when one is sighting up a slope the crossarm is turned just enough to compensate for extra distance due to slope.

If he does not use a monocular, the forester will probably have to

make his own instrument, at least for the time being, since there are none on the market. It is certain, however, that very soon a variety of useful tools will be devised, including folding models. A peep sight and a crossarm mounted on opposite ends of a cruising stick would make a useful combination. Actually, peep sights are not necessary, though they do serve to reduce parallax and to concentrate the attention.

More testing is needed to learn the proper shape for the crossarm sight. Bitterlich used a solid piece of metal, sighting off the edges. Later, in his Relascope, he used a piece of opaque plastic with a rectangular notch at the top. It is likely that the solid piece and the notch give opposite bias. It may be that some sighting device incorporating both the notch and the edge would be useful. Experience so far points out that, whatever the shape of the sight, the edges should be sharp, so that they will not allow light reflection to distort the view of the tree. Stage made a sight of clear plastic with a sharp notch at the top and an etched mark farther down. This allowed him to check his judgment against two different gauges at once.

In his tests in 1951 Stage found that he could use his thumb or a finger as a crossarm held at arm's length and get reasonably satisfactory results. This technique would eliminate the need for any instrument. For best results, Stage suggests selecting the finger or fingernail which will have a ratio of arm length to crossarm of 33 to 1 and which will thus permit use of a basal-area factor of 10. It is possible to calibrate one's fingers by sighting at a measured tree from a point that is located 33 times the tree diameter away. If the fingers or nails are not of proper size, a small piece of plastic of the correct size and shape may be held in the fingers at arm's length. A penny might be used in similar fashion, or the end of a stick, such as a cruising stick, might be shaped as a sight and held firmly in the fist. With hand-held "sights" it is important, of course, that they be at right angles to the line of sight, so that their full width is employed. The use of the arm and fingers will not be so accurate as an instrument, but they are always available. Theoretically, for a 25-inch reach, a crossarm measuring 0.7575 inches must be held within a tolerance of ± 1.5 inches in order to keep the estimate of basal area per acre within 10 per cent of error. It would seem that this tolerance could easily be held if the elbow were locked.

Slopes introduce problems in the Bitterlich method similar to

those they introduce in the method using fixed-radius plots. Trees should be judged on the horizontal. On a slope the tree count is bound to be smaller unless some correction is made for the angle of slope. Bitterlich's Relascope is the best way to solve the problem, since it automatically changes the critical angle to conform to the slope. With other instruments the tree count should be multiplied by the secant of the slope angle. This correction is theoretically sound even though some of the trees may be located on the same contour as the counting point. A table of secants for slopes commonly found might be glued to the instrument.

Application

While the Bitterlich system can be used to make volume estimates and to get other valuable survey statistics, its greatest usefulness will probably be in making quick basal-area estimates. Basal area is still the most satisfactory measure of stocking, but often it has not been computed because of the work involved beyond the usual calculations of volume. Now that it can be easily measured, we may look forward to its greater use.

The basal-area estimates arrived at by the Bitterlich system have greater inherent variation than do similar measurements made by use of fixed-radius plots. This means that the Bitterlich estimates have slightly greater standard deviations and slightly greater standard errors of mean. The tree counts are so much more quickly made, however, that this more than compensates for the lesser accuracy. In Stage's study the variation in basal-area estimate was such that thirty-two locations would have to be estimated by the Bitterlich technique to yield the same accuracy of mean as the twenty-four fixed-radius plots gave. However, to calculate basal area on a fixed-radius plot would take about fifteen minutes of field and office time, as contrasted with a maximum of two minutes for the tree-count technique. The result is that there is a saving in time of 82 per cent when the Bitterlich method is used. In Keen's study of fifteen locations by means of Bitterlich's Relascope, it was estimated that the saving in time was 60 per cent.

When all sizes of trees are included in the tree counts, the estimate is an estimate of total basal area per acre. To get basal area of trees over a given d.b.h. limit, it is necessary simply to ignore qualifying trees below that limit. If the diameter of each counted

tree is estimated and recorded by d.b.h. class, then basal areas can be determined by those classes and these figures when divided by the basal area at the class midpoint, as read from basal-area tables, will give a stand table. For accuracy within d.b.h. classes the counts must, of course, be taken from a number of points, to yield a sufficiently large sample. Species separations can also be made if desired, but they will be by basal area, not by number of trees. Often this type of separation is really what is needed in type-mapping.

Average d.b.h. or d.b.h. of the tree of average basal area is difficult to compute by the Bitterlich method. This is so because the count is proportional to basal area, but the total number of trees per acre is not obtained. The technique of computing must be a roundabout one, and is rather complex, as a study of Grosenbaugh's article (4) will show.

Volume estimates are easily derived from the tree count made by Bitterlich's method. The figure for the basal area per acre needs only be multiplied by a figure which gives the volume associated with a square foot of basal area. These ratios of board feet, cubic feet, or cords per square foot can be determined if suitable volume tables are converted into ratio tables by dividing the given volumes by the square feet of basal area associated with the various diameters. A tally of the counted trees by diameter and height will then indicate which ratios were sampled and these can be averaged to get the average ratio, which is multiplied by the basal area to give the volume estimate.

The Bitterlich method permits rough volume estimate as an easy additional process in the field. The ratios of volume to basal areas are only slightly variable within tree-height classes. This is true because basal area is the principal variable in volume, and so appears in both numerator and denominator of the ratio. The variation that remains within a height class must therefore be due to tree form and other variables which have little weight. Average ratios can consequently be selected in each height class and diameter ignored. The tree tally is kept only by the height classes. Where just two or three height classes are found, the problem of volume estimation becomes quite simple. Thus if the median height class is 1.5 logs and the average tree count is 8 trees per point occupied and the basal-area factor is 10, then the cruiser would multiply 8 by 10 to get basal area per acre and multiply this figure by the average

ratio for 1.5-log trees—say, 100—to get an estimate of 8,000 board feet per acre. Only a few ratios would have to be remembered.

Other uses of the point-count technique have not been fully developed as yet. Grosenbaugh (4) presents in his article some spatial distribution calculations that are probably of interest only to statistically inclined foresters, but he also sketches another, more practical use in connection with reproduction studies. With a minimum basal area chosen as a stocking guide, it would be possible to use a large critical angle such that the count of at least one tree would mean satisfactory stocking. Milacre studies of seedlings would then need to be made only when the basal area of established trees was found not to be sufficiently large.

The Bitterlich method should be particularly useful in selecting trees as subsamples for growth-rate and cull determination. The bias met with in sampling the nearest tree to plot center or the trees at predetermined points along strips is well known, and is commonly avoided by selecting as samples all trees on a definite subsample area. These samples could be much more easily selected by the point-count method described in this paper, and the effect of density variations on growth rates would be automatically allowed for.

In retrospect, it is a little astonishing that a fundamentally different estimating technique such as Bitterlich's should come along at this stage of mensurational development. It is a new and interesting forestry tool, whose possibilities have not yet been completely explored.

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LINE TREES IN NORTHERN MICHIGAN

GENE A. HESTERBERG

MANY of the original land surveys that subdivided the virgin forest areas of the Lake States region are now more than one hundred years old. The early Michigan rectangular survey, started in 1803, was completed in 1860. Wisconsin's subdivision was initiated in 1833, and most of that area had been examined by 1865. The Minnesota survey, started in 1848, was not completed, however, until 1900.

Wherever original surveys transected forest areas, the section corners and quarter-section corners were established by determining the compass bearing and the distance, usually measured in links of a surveyor's chain, from one or more near-by healthy forest trees. The trees at these corners were blazed as permanent monuments for the survey, and were then referred to as "bearing trees" or "witness trees." In a few instances the identifying feature of a section corner was a large, durable stone, a squared post of durable wood, or, more rarely, a length of metal pipe driven into the ground. Sometimes, however, early surveyors dug a shallow pit, into which they piled a cairn of rocks. The principal criterion in the choice of material was durability. Venerable bearing trees, many of them blazed more than one hundred years ago, are among the most useful markers of the section corners for the original surveys.

In addition, in the Upper Peninsula of Michigan trees (called "line trees") were marked at known stations along the section line. Two line trees were usually established between each section corner and quarter-section corner.

Use of trees to indicate section corners, quarter-section corners, and section lines originated with the first legislation introducing the rectangular system of surveying the public domain. First reference to the use of trees to mark survey locations in the United States and to serve as monuments for important survey stations is made in the Ordinance of May 28, 1784 (1), which provided for the mode of disposal of lands in the "Western territory." In part, this regulation states: ". . . lines shall be measured with a chain; shall be

plainly marked by chaps [chops] on the trees, and exactly described . . . ."

More elaborate instructions were issued later. In 1815 Edward Tiffin, then Surveyor General of the Lands North of the Ohio, provided a more thorough description of methods suitable for the survey of lands in the Lake States region. According to Stewart (2), these directions served as a model for numerous early accounts of survey techniques which appeared between 1815 and 1855. Tiffin instructed his deputies concerning the use of trees as survey reference points as follows: "All those trees which your line cuts must have two notches made on each side of the tree where the line cuts . . . there will be one or two sight trees [line trees] marked between every quarter-section corner." The species of tree, its estimated diameter, and its distance along the section line was to be recorded in the field book.

The two notches or "hack marks" by which the original survey trees can be identified are not the same as a blaze mark as we ordinarily know it now. In the 1947 government *Manual of Surveying Instructions* (3, p. 235) the notch, or hack mark, is differentiated from the blaze by the following definitions:

> A "blaze" is an artificial mark which is ordinarily made upon a tree trunk at about breast height, in which a flat scar is left upon the tree surface. The bark and a very small amount of the live wood tissue are removed, leaving a smooth surface which forever brands the tree. The size of the blaze depends somewhat upon the size of the tree, but is never made larger than the surface of an ax blade; a blaze 5 or 6 inches in height and from 2 to 4 inches in width is ample to mark any tree.
>
> A "hack" is also an artificial mark which is ordinarily made upon a tree trunk at about breast height, in which a horizontal notch is cut into the surface of the tree. The notch is made "V-shaped" and is cut through the bark and well into the wood. Two hack marks are cut in order to distinguish those made in the survey from accidental marks resulting from other causes; a vertical section of the completed official hack resembles a "double-V" ($\lesssim$) extending across a tree from 2 to 6 inches in length, depending upon the diameter of the tree. The "hack" and "blaze" marks are equally permanent, but so different in character that one mark should never be mistaken for the other.

Most of the virgin forest in Michigan through which the original rectangular survey was extended has now been logged, and only

scattered remnants of the old-growth stands of pine and northern hardwoods remain. In some areas trees used for land markings have been entirely destroyed by forest fires. Nonetheless, original witness trees and bearing trees are commonly found in survey work and in timber cruising. Line trees, however, are seldom seen, for many of them were unintentionally felled during logging operations

TABLE I

DESCRIPTION OF SURVEY STATIONS FROM THE ORIGINAL FIELD NOTES FOR TOWNSHIP 54 NORTH, RANGE 36 WEST, MICHIGAN MERIDIAN, HOUGHTON COUNTY, MICHIGAN*

"North between Section 1 and 2. Variation 7° East.
12.22—Hemlock 12" at corner
31.17—Hemlock 14"
40.00—Set ¼ Sec. post
Sugar 22" S 46 E, 3 lks.
Sugar 10" N 38 W, 5 lks.
51.06—Maple 14"
72.19—Sugar 18"
79.89—Intersect North Boundary, 7 lks. E of post
Set post corner Sec. 1 and 2.
Maple 14" S 43 W, 9 lks.
Y. Birch 12", S 70 E, 4 lks.
Land level, 1st rate
Sugar, Lynn, Ironwood, Hemlock, Balsam, etc."

* The numbers at the left indicate the distance of each station in chains and links north from the southwest corner of Section 1. In addition, the species and the diameter of each line tree was recorded. Entries concerning bearing trees give the species and the diameter of the tree and the bearing and the distance (in links) from the corner to each witness tree. The surveyor's final remarks indicate that the land was level and was "first-rate" forest, consisting of sugar maple, basswood ("Lynn"), ironwood, hemlock, balsam fir, and other trees. The original notes were recorded on July 9, 1846.

because callus tissue had overgrown the identifying hack marks. An account of the discovery of two lines trees in virgin northern hardwood forest of the Keweenaw Peninsula is therefore worthy of record.

During the summer of 1949 an attempt was made, with the aid of James Lamy, of the Division of Forestry, Michigan Department of Conservation, to reëstablish an obliterated section corner. The

corner was common to Sections 1, 2, 11, and 12 in Township 54 North, Range 36 West, Houghton County, Michigan. Although its approximate location was ascertained, there was not time to make the detailed survey required to reëstablish it precisely. During the summer of 1950, however, a small crew completed the necessary field work, and the crew chief, John Hornick, located two line trees, which were identified as station markers established in the original survey of 1846.

Field notes made during the original survey for the line between Sections 1 and 2 are presented in Table I. The 12-inch hemlock, recorded at 12.22 chains north of the southwest corner of Section 1 (Table I), was the first of the two line trees discovered. The hack marks, at breast height and 8 inches apart, were heavily overgrown with callus tissue, and they could easily have gone unnoticed by the casual observer (Pl. I). The second tree was located along the south line of Section 2 in the same township and range. This was a yellow birch, 24 inches in diameter, whose century-old hack marks had likewise been overgrown by callus.

The exact section-corner location could not be determined, beyond reasonable doubt, either from traces of the witness trees or from other reliable evidence of the original monument. Since the line trees represented the nearest definite stations of the 1846 survey, they were useful in reëstablishing the obliterated section corner. By locating the section corner in the position which it originally occupied on the ground, a dispute regarding land boundaries was avoided and future transfer or exchange of forest property was facilitated.

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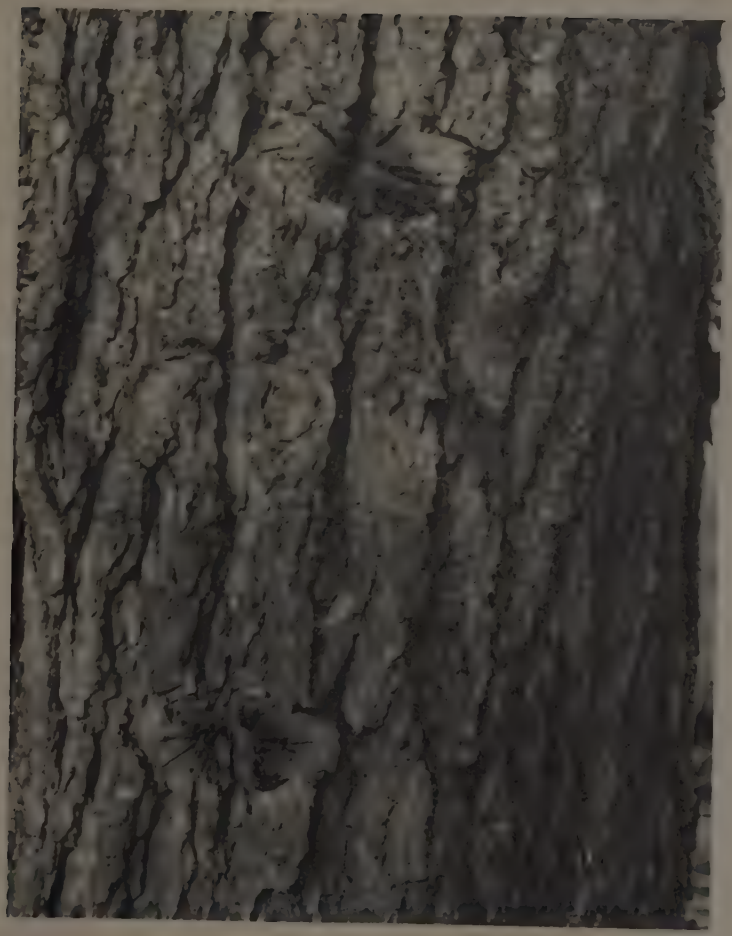

Line tree—a hemlock 28 inches in diameter—showing callus-covered hack marks made in 1846, during the original Michigan land survey

SOME EFFECTS OF SPACING ON JACK-PINE DEVELOPMENT IN LOWER MICHIGAN AFTER TWENTY-FIVE YEARS

ROBERT A. RALSTON

IN STARTING a plantation the initial spacing interval between trees is of prime importance and is a factor that can be controlled. Other things being equal, the planting density which is best depends mainly upon expected growth, mortality, and the size of the material to be harvested in the first thinning. Inasmuch as mortality, future markets, and, to some extent, growth are difficult to predict accurately, it is often a real problem to select the right planting interval for a given species and site.

In lower Michigan most of the land which should be planted to jack pine (*Pinus Banksiana* Lamb.) is of relatively poor site quality. Pulpwood will probably continue to be one of the main raw materials produced because of industrial needs and the slow growth on the poorer sandy soils in this region. Low yields and low-value products militate against noncommercial thinnings even though they may be silviculturally desirable. Under these conditions, the need for providing adequate growing space in plantations should coincide with the attainment of merchantability of the trees to be removed.

Successful timing of the first commercial thinning is not always possible if nature is imitated in artificial reforestation. As a direct result of slow growth and the delayed expression of dominance, well-stocked natural stands on poor sites normally carry more stems per acre at a given age than those on good sites. This delayed expression of dominance may be even more pronounced in regularly spaced even-aged plantations than in irregularly spaced less-even-aged natural stands. For example, a jack-pine plantation in Vermont on sandy loam soil was planted at the rate of 10,890, 2,720, 1,210, and 681 seedlings per acre. Twenty-eight years later there were 6,000, 2,100, 1,000, and 520 trees per acre still living (2). According to a yield table for well-stocked stands of natural jack pine on average sites in the Lake States, there should be only 875

stems per acre left after thirty years out of 1,700 stems present at twenty years (3).

European practice is to space planted trees very closely, especially on the poorer soils, to insure full utilization of the site in a short time. Needed thinnings are made when the plantations are very young, since a market exists in Europe for material of almost any size. The opportunity for commercial thinnings does not usually arise in lower Michigan, however, until from three to four cords of pulpwood per acre can be cut from two-stick trees. Moreover, present returns from these less-productive timberlands do not justify noncommercial thinnings regardless of the silvicultural need. If a market should develop for smaller material, such as that used for posts, the situation would be somewhat improved.

To provide more specific knowledge about spacing planted jack pine, several long-time studies are being carried on in the Lake States region. Ten-year results have been reported recently (4; 5). The present paper describes one test established by members of the Huron National Forest staff to investigate the growth, yield, and value of jack pine at three different spacings. The results of this administrative study, now twenty-five years old, provide a limited opportunity to evaluate spacing standards for jack pine on poor sites in lower Michigan.

The Experiment

In the spring of 1925 a three-acre jack-pine plantation was established on Grayling sand along the south bank of the Au Sable River, about six miles west of the Lumberman's Monument in Iosco County, Michigan. This site is typical of the poorer, sandy, jack-pine planting "chances" on the outwash plains of lower Michigan. Jack pine, 1–0 stock, was bar-planted in furrows at three spacings—4 × 4, 6 × 6, and 8 × 8 feet. A one-acre-square plot was devoted to each spacing. The unreplicated plots were laid out side by side on a site occupied by a sparse stand of scrubby northern pin oak (*Quercus ellipsoidalis* Hill). Preplanting release was not necessary, but all overtopping oaks were removed in 1939.

Survival at the end of the first growing season was 78, 71, and 59 per cent for the 4 × 4, 6 × 6, and 8 × 8 foot spacings, respectively. All fail spots were replanted the following spring with 2–0 stock. Some replanting was also done in the spring of 1927. Meas-

urements in the fall of 1936 showed survival percentages similar to those of 1925 before the original replanting. It appears that the plots developed at average spacings of about 5 × 5, 7 × 7, and 9 × 9 feet during much of the early, formative period.

Effect of Spacing

After twenty-five years of growth at three densities of stocking, significant differences in stand development are evident (Table I). Diameter growth, as would be expected, increased with spacing interval, averaging 3.1, 4.1, and 4.6 inches d.b.h. for the original

TABLE I

Stand Development per Acre, 1925–51

Spacing between trees, in feet			Total number of stems			Basal area, in sq. ft., 1951	Volume, 1951	
1925	1936	1951	1925	1936	1951		Cu. ft.	Cords*
4 × 4	5 × 5	5 × 6	2,722	1,620	1,500	78	800	3.9
6 × 6	7 × 8	8 × 8	1,210	780	730	67	740	7.8
8 × 8	10 × 10	10 × 11	681	425	390	45	540	5.4

* One hundred inches long to a 3-inch top d.i.b. from trees 3.6 inches d.b.h. and up.

4 × 4, 6 × 6, and 8 × 8 foot plots, respectively (Table II). The distribution of stems by diameter classes is limited to a narrow range; most of the trees are within one inch class of the average size (Table III).

Height growth has been unaffected by differences in spacing. The stand has grown about one foot in height annually regardless of density of stocking during the twenty-five-year period (Table II). These results have generally been substantiated by the findings of others working with jack pine in several regions (1; 4; 5).

Present stockings are 1,500, 730, and 390 trees per acre for the original 4 × 4, 6 × 6, and 8 × 8 foot spacings, so that the present spacings are about 5 × 6, 8 × 8, and 10 × 11 feet. The causes of mortality cannot be definitely determined since early records are nonexistent. The plantation has come through several very dry years, though, which must have exacted a heavy toll; it is probably safe to assume that much of the early mortality was caused by

drought and heat. There is visual evidence, however, of white-pine weevil damage and loss through competition.

Volume growth has amounted to 3.9, 7.8, and 5.4 cords per acre of 100-inch pulpwood to a 3-inch top d.i.b.[1] in the original spacings

TABLE II

AVERAGE HEIGHT AND DIAMETER GROWTH OF JACK PINE TEN AND TWENTY-FIVE YEARS AFTER PLANTING

Original spacing, in feet, 1925	Average height of dominants, in feet		Average d.b.h., in inches, 1951
	1936	1951	
4 × 4	7.4	25.7	3.1
6 × 6	7.5	25.6	4.1
8 × 8	7.8	25.2	4.6

TABLE III

DISTRIBUTION OF TREES PER ACRE BY DIAMETER CLASSES, 1951

D.B.H. class, in inches	Average spacing, 1951					
	5 × 6 ft.		8 × 8 ft.		10 × 11 ft.	
	Trees	Percentage	Trees	Percentage	Trees	Percentage
1	135	9	9	1	...	..
2	375	25	42	6	8	2
3	615	41	118	16	46	12
4	355	24	354	49	137	35
5	20	1	198	27	191	49
6	...	..	9	1	8	2
Total	1,500	100	730	100	390	100

of 4 × 4, 6 × 6, and 8 × 8 feet. About 35 per cent of the trees of the original 4 × 4 foot spacing (now 5 × 6) have slowed down almost to a standstill in growth, and only about 25 per cent of the stand can be considered good growing stock. Nearly 80 per cent of the trees of the 6 × 6 foot spacing (now 8 × 8) are still growing as well as could

[1] All trees 3.6 inches d.b.h. and up are considered merchantable.

be expected considering the site, and should provide adequate stocking for one or two commercial thinnings before the final harvest. The 8 × 8 foot spacing (now 10 × 11) is too open and "orchard-like," and cannot possibly produce maximum yields on this site. Only 25 per cent, 375 trees, at the 4 × 4 foot spacing are of commercial size, and all but 20 of these trees are in the 4-inch diameter class (Table III). The area with 6 × 6 foot spacing has 561 merchantable trees per acre, while that with the 8 × 8 foot spacing has only 336 per acre.

Field observations show that the trees planted at 4 × 4 foot spacings, which are now about 5 × 6 feet apart, are in need of thinning, but that on the average they are too small to justify a commercial operation. The plot originally started at a 6 × 6 foot spacing and now at about an 8 × 8 foot spacing looks the best and should be ready both silviculturally and economically for a light thinning in five years. The area that was planted at an 8 × 8 foot spacing, which is now 10 × 11, has too many excessively limby, open-grown trees. This plot probably will not be thinned on a rotation of fifty years.

Discussion

Under existing conditions in lower Michigan, noncommercial thinnings are not feasible in jack-pine-plantation management. Even though it might be possible to grow more wood per acre by close spacings requiring one or more thinnings before the stand reaches merchantable size, this practice cannot be justified at present. It is valuable to know, however, just how stand density affects the growth and development of jack pine on various sites. The test reported here indicates that early crown closure on poor sites can be secured only at the expense of volume growth. Perhaps it should be recognized that spacing on both good and poor sites should be about the same, after expected mortality is discounted. If size alone is considered and age is disregarded, poorer sites usually have fewer trees per acre than better sites for any given average stand diameter. For example, a yield table for well-stocked natural jack-pine stands in the Lake States shows that on good sites after forty years there should be 435 trees per acre averaging 8 inches d.b.h. On poor sites, however, only 330 stems per acre, averaging 8 inches d.b.h., can be expected at the end of eighty years

(3). The question immediately arises as to the value of close spacing, early crown closure, and noncommercial thinning as compared with wider spacing, delayed closure, and commercial thinning.

The quantitative and qualitative results of this planting test show that spacings for jack-pine plantations on poor sites should be about 6 × 6 feet if there is reason to expect no more than 50 per cent mortality. Even assuming such a relatively high rate of loss, 600 trees per acre will be available when the first commercial thinning is considered, after about thirty years. Another factor to be taken into account in reforestation is the cost of planting. The cost of 6 × 6 foot spacing in machine planting can be less than one half that of 4 × 4 foot spacing (6). A 6 × 8 foot spacing with the furrows 8 feet apart will reduce costs even further.

Summary

A twenty-five-year-old jack-pine spacing test in the Huron National Forest in lower Michigan furnishes evidence that plantations on poor sites with an initial spacing of about 6 × 6 feet will yield sufficient merchantable products for a commercial thinning when thinning is needed silviculturally. Height growth is unaffected by density of stocking, but diameter increment increases with wider spacing. Trees in spacings wider than 8 × 8 feet, however, although attaining larger diameters, are limby, "orchard-like," and will not fully occupy the site. A total of from about 600 to 700 stems per acre at this age—twenty-five years—looks like the best stocking for maximum return. Spacings of 6 × 6 feet with 50 per cent survival, or 6 × 8 with 70 per cent survival, should provide enough trees for a beneficial commercial thinning after about thirty years.

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